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DEVELOPMENT OF ENGINEERING DATA ON ADVANCED COMPOSITE MATERIALS

University of Dayton Research Institute
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Advanced Composites	Interlaminar Shear	Glass Transition Temperature
Tension	Fatigue	Specific Heat

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Engineering data have been generated on six advanced composite materials; T300/AFR800 (graphite/epoxy ~~by Hexcel~~); SiC/5506 (silicon carbide/epoxy ~~by AVCO~~); HyE 2034D (pitch based graphite/epoxy ~~by Fiberite~~); T300/V378A (graphite/polyimide ~~by U.S. Polymeric~~); HyE 1076J (graphite/epoxy ~~by Fiberite~~); and 6535-1 (graphite/epoxy ~~by AVCO~~). Prepreg tape was obtained from each vendor and laminates and test specimens prepared ~~at UDRI~~. Five different static mechanical properties (tension, compression, flexure, inplane shear, and → next page

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interlaminar shear) were measured on various fiber orientations at four different temperatures (-67°F, 72°F, and two elevated temperatures). Tensile fatigue, creep, and stress-rupture tests were also conducted and four thermophysical properties (thermal expansion, thermal conductivity, specific heat, and glass transition temperature) were determined. Environmental agings (at 160°F and 100 percent relative humidity) were conducted on each material and the effects on this exposure on several mechanical properties were determined. On four of the materials, tests were conducted on specimens with a hole located in the center of the gage section. On the last material, three different ply stacking sequences incorporating 0°, 90°, and ±45° plies were tested. These three different sequences gave rise to tensile, compressive, and zero stress in the thickness direction at the specimen free edges.

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PREFACE

This summary report covers work performed during the period from 1 September 1978 to 30 September 1981 under Air Force Contract F33615-78-C-5172. The contract was initiated under Project Number 7381, "Materials Application". The work was administered under the direction of the Systems Support Division of the Air Force Wright Aeronautical Laboratories/ Materials Laboratory, Wright-Patterson Air Force Base, Ohio. Mr. David Watson (AFWAL/MLSA) acted as Project Engineer.

This work was conducted under the general supervision of Mr. D. Gerdeman, Project Supervisor. The Principal Investigator for this program was D. Robert Askins. Research Technicians who made major contributions to the program include: R. J. Kuhbander, D. Byrge, R. Glett, R. Rondeau, D. Pike, D. Miller, and W. Miller.

The author is also indebted to Dr. Fred Bogner for the analysis and computation of normal edge stresses in the multi-directional laminates.

This report was submitted by the author in October 1981. The contractor's report number is UDR-TR-81-85.

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SECTION 1

INTRODUCTION

Fiber reinforced composite materials have been used in Aerospace structures for many years. The use of these materials is continually growing, and as new fiber reinforcements and matrix materials become available, the problem of selecting materials becomes an ever-growing task for aircraft builders and designers. In order to screen and select materials for a particular aircraft structure, a certain minimal amount of engineering data must be available to the aircraft designer. The data base from which this information is extracted must be continually updated and supplemented so that the spectrum of available candidate composite systems for consideration be broadened in step with the latest technological advancements. Data such as this are intended to reduce the time lag between the development of a new composite material system or component and its eventual use in an aircraft system. The general objective of this program was to develop engineering data on advanced composite materials. These materials were to be newly developed composite materials systems which were commercially available, but which at the same time were new enough that little data was available for the purpose of evaluating their potential. The purpose was to generate physical, mechanical, and thermophysical properties on a number of these advanced composite materials. The data generated in this program are not sufficient to eliminate the need for more detailed and more comprehensive design data programs. Rather, an initial data base is developed to facilitate the selection of candidate materials, and which provides a basis for developing subsequent design allowable efforts on selected materials. It provides the information required to make preliminary assessments of composite materials for potential aerospace service.

SECTION 2
SELECTION OF MATERIALS

The initial portion of the program involved an identification of available candidate composite materials. Both written and verbal contact was established with a wide cross-section of industry and government representatives who are active in the area of composite materials research, development, and application. Letter questionnaires were sent to individuals representing all the services, all the major aircraft companies, and nearly all of the major material suppliers. The questionnaire was directed toward obtaining each individual's feelings as to what materials should be considered for inclusion in this program, what their assessment of the current data availability on the various materials was, and their feelings as to potential applications for which the various advanced and newly available composite material systems might be considered. In addition, these representatives were asked what they felt the most useful and most needed type of engineering data were, as well as their feeling about the effect of manufacturing processes required for a specific composite material or its potential usage by the Aerospace community. These letter-questionnaires were sent to a total of 111 individuals. A total of 16 written responses were received, representing 14 percent of the total mailing. In addition to the written inputs numerous telephone contacts were made with individuals who did not respond in writing to our questionnaires and to obtain additional information to that requested in the letter. All the verbal as well as written inputs to this phase of the program were tabulated and discussed with Air Force Wright Aeronautical Laboratory/Materials Laboratory (AFWAL/ML) representatives prior to the establishment of a list of tentative candidate materials for possible inclusion in the program.

The criteria employed to determine and select these candidate materials included (a) the present or imminent commercial

availability of the material, (b) the degree of interest in the material expressed in the written responses and telephone contacts, (c) the material's potential to overcome specific problems of current concern to the United States Air Force (USAF), and (d) the potential value to the USAF if the material proves applicable to Air Force weapons systems. The candidate material identification and selection process was a continuing activity throughout the program. As new materials were learned of they were added to the candidate list and telephone inquiries were initiated to learn as much as possible about the material. A total of six composite systems were ultimately selected from among the candidates for inclusion in the data generation effort. These six selections were made approximately every six months starting at the beginning of the program. Table 1 lists the candidates which were considered at one time or another. In most cases a fiber or resin matrix candidate is listed alone.

The six composite material systems ultimately selected were:

(1) T300/AFR800 by Hexcel,
(2) SiC/5506 by AVCO,
(3) HyE 2034D by Fiberite,
(4) T300/V378A by U.S. Polymeric,
(5) HyE 1076J by Fiberite, and
(6) 6535-1 by AVCO.

The T300/AFR800 system was selected because it is an epoxy system which does not require refrigerated storage. It was developed by the Aerotherm Division of Accurex Corporation under contract to the Air Force Materials Laboratory to compete with 350°F (177°C) epoxy systems.

The silicon carbide/5506 system was selected because of the silicon carbide fiber. This fiber, on a carbon substrate, was developed by the AVCO Corporation and provides properties essentially equivalent to boron fiber but has a potentially

TABLE 1

CANDIDATE MATERIALS

Material	Comments
1. PKXA	A silane terminated polysulfone. This feature permits some end group cross-linking which improves solvent/moisture resistance and temperature capability.
2. HyE 1076E	A graphite/epoxy system alleged to be more moisture resistant than Narmco's 5208. Also supposed to be a higher elongation matrix than other 350°F (177°C) class epoxies.
3. HMF-351/76	Same as #2 except a woven fabric.
4. CPI-2272	A polyimide resin alleged to have equivalent or better moisture resistance and temperature capability than F178.
5. NCNS	Developed to replace the M4-720 base resin used in 350°F (177°C) class epoxies. It is fire retardant, generates little smoke, and is water resistant.
6. PMR-II	Second generation material claimed to have higher temperature capability than PMR-15.
7. X904B	A non-proprietary 350°F (177°C) epoxy system developed under USAF contract. Reputed to have low moisture absorption.
8. E788	An elastomer modified epoxy system.
9. LARC 160	A 550°F (288°C) polyimide supposed to have better handling and processing characteristics than PMR-15.
10. AS/3006	A graphite/polyphenylsulfone (Radel PPS) system which processes easily and has good water resistance. Main short-coming is solvent resistance leading to stress-cracking.
11. DAPI	Diaminophenylindane. A thermoplastic with 500°F (260°C) service capabili[illegible] and which processes easily. Its so[illegible] resistance is principal problem.

TABLE 1 (Continued)

CANDIDATE MATERIALS

Material	Comments
12. Pitch-based graphite fiber	Three grades are being developed, having nominal modulii of 55 msi, 75 msi, and 100 msi. This fiber is potentially very inexpensive.
13. Glass matrix composites	High temperature capability. Excellent dimensional stability. Water and solvent resistant. Not yet commercially available.
14. FP alumina fibers	Potential for low cost makes it a candidate to replace boron.
15. SiC/epoxy	Silicon carbide on a carbon substrate has properties equivalent to boron but has a much lower cost potential.
16. Phthalocyanine	A new matrix system being developed. It is alleged to have high toughness and good elevated temperature capabilities.
17. V378A	A polyimide system with improved wet high-temperature properties. Microcracking is supposed to be substantially reduced.
18. Thermid 600	Acetylene terminated polyimide system with 550-600°F (288-316°C) service capabilities.
19. XPL 1056	This vinyl polyester resin system cures very rapidly at relatively low temperatures and pressures. Preliminary tests indicated very good moisture resistance. The material also appears to form a better bond to aramid fibers than epoxy resins, leading to higher shear and compression properties.
20. High filament end graphite tow	Larger graphite tows now being developed reduce prepreg preparation costs.

TABLE 1 (Concluded)

CANDIDATE MATERIALS

	Material	Comments
21.	AFR800	An epoxy resin system developed under Air Force contract which has a long room temperature shelf life.
22.	NR150B2	Probably the highest service temperature organic matrix system available. Very difficult to process.
23.	RX-6450	N-cyanosulfonamide. An addition type resin that cures like conventional epoxies but offers better temperature capabilities and greater environmental resistance.
24.	PSP 6002	This polystyrilpyridine resin is a heterocyclic aromatic polymer which appears to offer very good high temperature performance. It was developed in France.
25.	Ryton	This polyphenylene sulfide material retains good mechanical property levels up to 300°F (149°C), has excellent chemical resistance, and is relatively easy to process.

much lower cost. The 5506 resin system was developed by AVCO as a 350°F (177°C) epoxy and was recommended by them for use with the SiC fiber.

The HyE 2034D material consists of Union Carbide's VSC-32 pitch-based graphite fiber in Fiberite's 934 epoxy resin system. The VSC-32 is a low cost 75×10^6 psi (517 GPa) modulus fiber which can favorably compete with boron in many applications.

The V378A resin is a 450°F (232°C) polyimide system which was developed by U.S. Polymeric and was of interest to many respondents to our mail and telephone inquiries. Initially, it was intended to characterize the resin on Celion 6000 graphite fiber with a polyimide (NR150B2) size but initial testing by U.S. Polymeric indicated that epoxy sized T300 produced better property levels with V378A. Rather than wait for further development work with other fiber finishes on Celion, it was decided to go ahead with T300 as the reinforcement.

The fifth material selected was HyE 1076J and consisted of Thornel 300 (15,000 filament tow) in Fiberite's new 976 epoxy, a 350°F (177°C) rated resin with better moisture resistance than the 934 system. Originally the fiber desired in this prepreg was Hercules' AS4 graphite in a 12,000 filament tow. This fiber, however, was not readily available at the time and in order to avoid a delay of uncertain duration, the T300 was substituted.

The last material tested was AVCO's 6535-1 graphite/epoxy prepreg system. This consisted of a 160,000 filament tow graphite fiber in a 350°F (177°C) class epoxy resin. Both components were AVCO products.

SECTION 3
TEST PROGRAM AND PROCEDURES

The laboratory efforts required during this program consisted of four generally sequential steps for each of the six materials characterized. These consisted of prepreg physical property characterization, laminate fabrication and specimen machining, laminate physical property characterization, and laminate mechanical and thermophysical property measurements. Each of the test methods and types of specimen used in the determination of these various properties, as well as the panel fabrication and specimen preparation procedures, are described in this section. Procedures or circumstances which were unique to a particular material are discussed in detail in the appropriate part of Section 4.

3.1 PREPREG PHYSICAL PROPERTY CHARACTERIZATION

The standard prepreg physical properties which were measured consisted of volatile content, resin content, and gel time. In addition, flow was measured on some of the materials and high pressure liquid chromatographic (HPLC) analyses were conducted on all but one of the prepregs. The specific test methods used to determine these properties are identified in Table 2 for each prepreg system. Detailed step-by-step procedures for each of the prepreg test methods listed in Table 2 are presented in Appendix B. The summarized prepreg properties themselves are presented in Section 4 for each specific material. These prepreg physical property characterizations were not intended primarily as a means of accepting or rejecting a particular batch of material. Rather, they were conducted to provide the reader with an indication of the normal property levels and variability encountered in purchased prepreg and also to provide a basis for the subsequent assessment of laminate properties obtainable from such prepreg.

TABLE 2

PREPREG PHYSICAL PROPERTY TEST AND SPECIFICATIONS

Prepreg Material	Test Specification Identification[1]			
	Volatile Content	Resin Content	Gel Time	Flow
T300/AFR800	HD-SG-2-6006C (5.1.2); Hercules	HD-SG-2-6006C (5.2); Hercules	HD-SG-2-6006C(5.5) Hercules	HD-SG-2-6006C (5.3.2B); Hercules
SiC/5506	4.2.3.3 Adv. Comp. Des. Guide	4.2.3.2.1 Adv. Comp. Des. Guide	---	---
HyE 2034D	QCI-C-V-14 Fiberite	R15 Fiberite	G2 Fiberite	QCI-C-F-42 Fiberite
T300/V378A	QCI-C-V-14 Fiberite	R15 Fiberite	G2 Fiberite	---
HyE 1076J	QCI-C-V-14 Fiberite	R15 Fiberite	G2 Fiberite	---
6535-1	QCI-C-V-14 Fiberite	R15 Fiberite	G2 Fiberite	---

[1]Each of the procedures identified in this table are presented in their entirety in Appendix B.

Reverse phase HPLC was used to separate the epoxy and polyimide resins into their constituent components. A 4.6 mm diameter by 25 cm long column packed with Zorbax ODS (by DuPont) was used in conjunction with a mobile phase of dioxane and water. A programmed concentration gradient for the mobile phase was selected for optimum peak separation and analysis time. In this program, the mobile phase started as 100 percent water to precipitate the resin at the head of the column. Increasing percentages of dioxane were added to separate and move the resin components through the column. Since reverse phase chromatography uses a non-polar support and a polar mobile phase, the more polar compounds elute first followed by less polar components as the mobile phase becomes less polar.

Samples for the prepreg physical property tests were obtained from each roll of prepreg tape and three specimens were used for each test. A complete tabulation of these prepreg test results is presented in Appendix B. All of the prepreg used in this program except for the T300/AFR800 was stored at -30°F (-34°C) when not in use and all of the laminates needed for the program were prepared prior to the expiration of the manufacturer's stated storage life of each specific material. In addition, a written record was maintained for each roll of prepreg which noted the cumulative total time the material was exposed to room temperature conditions during the period in which laminates were being fabricated from the tape. The T300/AFR800 material was stored at room temperature since this material was formulated to have extended room temperature storage life.

3.2 LAMINATE PROCESSING AND SPECIMEN FABRICATION

When laminates were to be made, the roll of prepreg was (except for the T300/AFR800 material) removed from the freezer and allowed to warm to room temperature without opening the sealed bag in which the prepreg was contained. This was done in order to eliminate the chance of moisture condensation directly on the prepreg material. After the prepreg had warmed thoroughly to room temperature, it was removed from its package and unrolled on a clean countertop. Pieces were cut from the tape in the required shape and size with a razor and after removing the release paper, carefully layed up in the desired stacking sequence for a particular laminate panel. This stack was then carefully rebagged and returned to the freezer for storage until lamination and curing. Normally ten or more laminates were layed up at the same time to minimize "out time" with the prepreg. When a laminate was to be cured, it was removed from the freezer and warmed to ambient before reopening its storage bag. The prepreg was then removed from the storage bag and incorporated into a

layup stack similar to that illustrated in Figure 1. This layup stack was assembled on the table platen in an autoclave. The detailed curing schedules for each specific prepreg material are presented in Section 4. After lamination and cure, machining diagrams were sketched onto the panel surfaces and individual specimens were cut out of the panels with a diamond cut-off wheel and finish machined to the required dimensions on a Tensile-Cut belt sander. In the case of the silicon carbide reinforced panels, the hardness of the fiber made final specimen machining so difficult that the laminates were finish cut to final dimensions on a special diamond cut-off wheel equipped with an accurately positioned movable table. Specimens from each panel were set aside for measurement of panel physical characteristics.

Most of the mechanical test specimens required doubling tabs in the grip sections. A 1/16-inch thick glass fabric reinforced phenolic laminate material was used for this purpose. Scotchply is specified in the Design Guide for tab material but it proved unsatisfactory for the elevated temperatures. Several adhesives were used to bond the tabs to the specimen. Originally Loctite 306 was used for all tab bonding. When multidirectional ply orientations, which required high loads, were introduced into the program; however, it was found necessary to switch to FM400 as a tab adhesive. M-Bond 200 was used as a tab adhesive on specimens which were humidity aged prior to testing because these specimens did not require high loads and this adhesive cured rapidly (three to five minutes) at room temperature, thereby minimizing specimen dryout. The FM400 was cured at 325°F (163°C) for one hour. The Loctite 306, when it was used, was cured for 15 minutes at 275°F (135°C). All tabs were clamped in place with spring clamps during adhesive cure.

3.3 LAMINATE PHYSICAL PROPERTY CHARACTERIZATION

Four different physical properties were measured on each laminate to insure acceptable laminate quality. These were

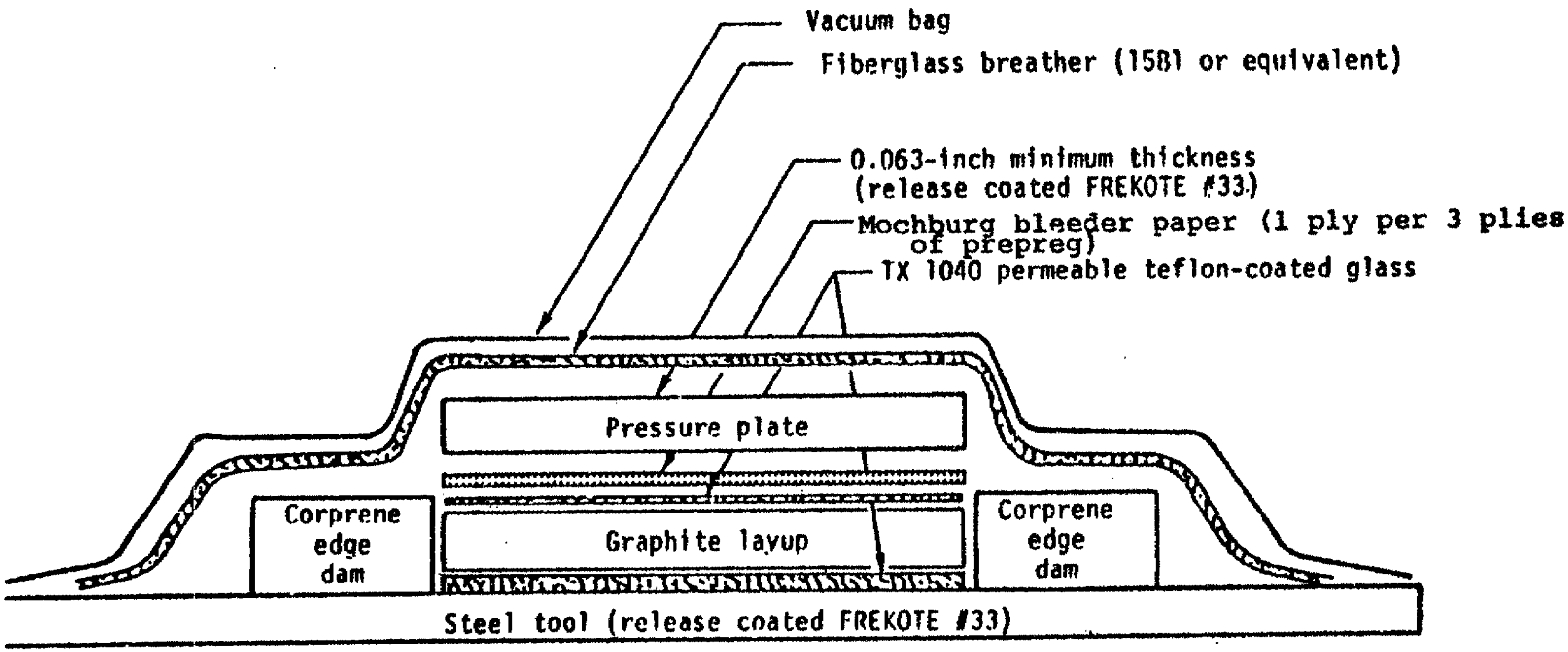


Figure 1. Typical Laminating Layup Stack.

specific gravity, resin content, fiber content, and void content. Each of the procedures used for these measurements is identified and discussed in the following paragraphs. The laminate physical properties obtained for each of the materials investigated are summarized in tables in Section 4 and are presented in their entirety in Appendix C.

3.3.1 Specific Gravity

Three specimens from widely scattered locations on each laminate were selected for specific gravity determinations. Specimen size depended upon both panel size and the number and size of mechanical test specimens required from the panel, but in general ranged from a minimum of 1/2" x 1/2" to a maximum of 1" x 3/4". The method used was ASTM D792, a weight-in-air/weight-in-water technique.

3.3.2 Resin Content

The same specimens which were used for specific gravity measurements were used for resin content determinations. The procedure used involved the digestion of the matrix resin in an acid solution at elevated temperatures. For the five epoxy matrix systems, the acid solution was 70% nitric acid at 145°F (63°C). For the polyimide matrix system (V378A), the digestion solution consisted of a mixture of 96% sulfuric acid and 30% hydrogen peroxide (80:20 volume ratio, respectively, in the mix) at 175°F (78°C).

3.3.3 Fiber Content

The fiber contents of the laminates were computed, as percent by volume, from the same data used for the resin content determinations. The computational procedure is illustrated in AFML-TR-67-243 and employed values for fiber and resin specific gravity reported by the respective manufacturers.

3.3.4 Void Content

The void contents, just as the fiber contents, were computed, as percent by volume, from the same data obtained

in the resin content determinations. The computational procedure is described in ASTM D2734, method B. The result of this procedure frequently gives negative values for laminates having low void contents. This occurs because minor inaccuracies in the values used for resin, fiber, and composite specific gravities become significant at low void contents. A negative result was obtained for numerous laminates made in this program, even though photomicrographs did sometimes reveal the presence of low levels of porosity. Figure 2 illustrates typical laminate cross sections for each of the composite materials characterized.

3.4 SPECIMEN CONDITIONING

Three different types of conditioning were involved in this program. The first was simply a dry dessicated storage of finished specimens at ambient temperature until they were to be tested. This provides a data base for the dry material to which both humidity aging data and data for other materials systems can be compared.

The second type of conditioning was the elevated and reduced test temperatures. In all of the mechanical testing except for specimens which were humidity aged, the specimens were soaked for one-half hour at the test temperature prior to loading. Thermal conductivity specimens were soaked at temperature for periods of from one to several hours in order to provide sufficient time for the test stack to reach thermal equilibrium before readings were taken. The thermal expansion and specific heat specimens were soaked for various periods of time at the endpoints of the test temperature brackets in order to permit stable baseline recordings to be achieved. These periods typically ran from five to 30 minutes in the specific heat tests to one-half to one hour in the thermal expansion tests. The glass transition temperature tests did not involve an isothermal soak since the specimen was heated at a constant rate throughout the test.

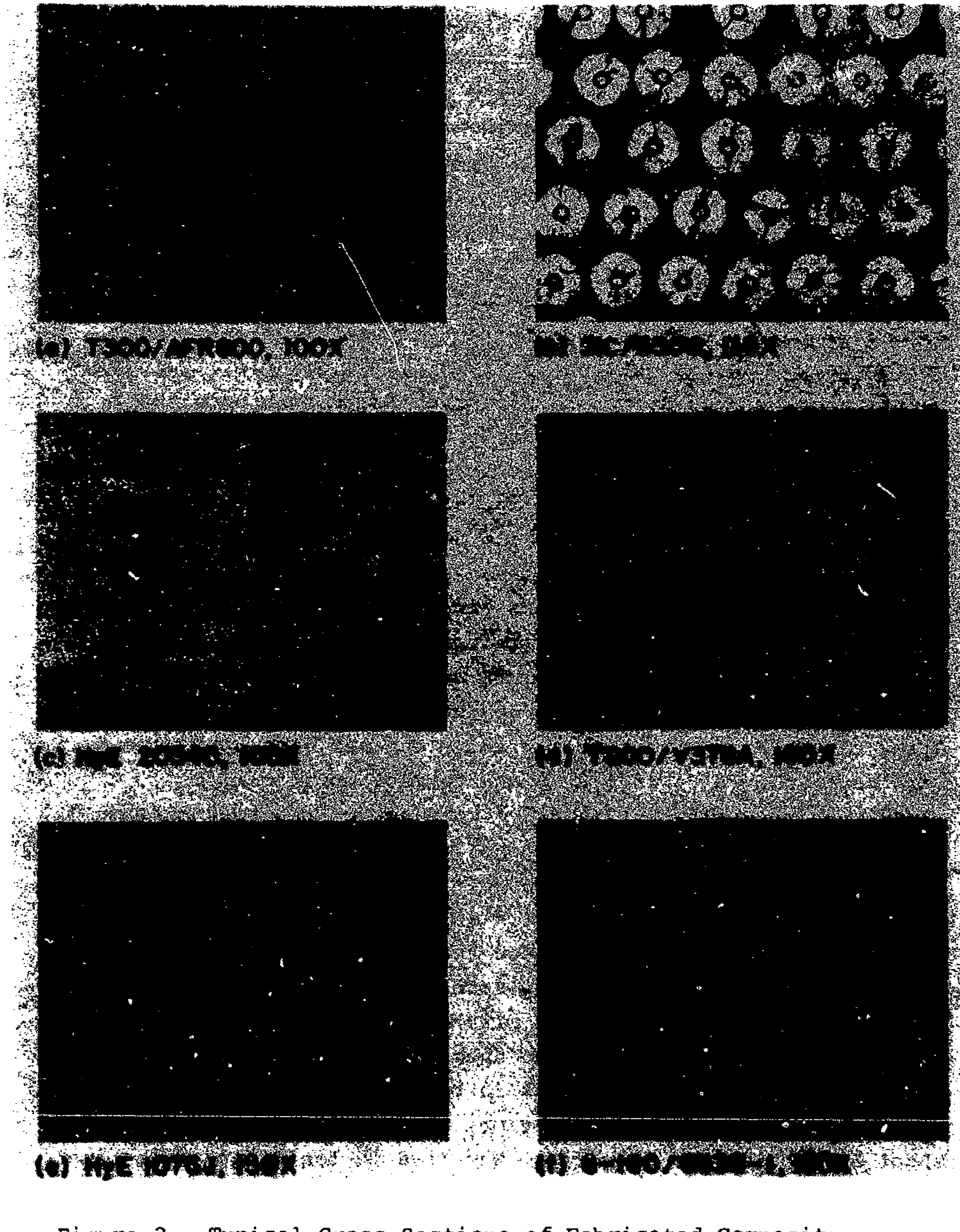


Figure 2. Typical Cross-Sections of Fabricated Composites.

The third type of conditioning was an elevated temperature, high humidity exposure. The specimens involved in these tests were exposed to conditions of 160°F and 100% R.H. until they either reached saturation, as evidenced by constant weight, or about 50% of their saturated weight gain. Specimens were removed from the humidity cabinets for weighing periodically to determine weight gain. The frequency of removal varied from material to material depending upon whether the aging was being carried to saturation or half-saturation and upon the rate and extent of moisture absorption by the particular matrix system being aged. The half-saturation agings, for example, typically required between 18 hours and nine days, depending upon the size of the specimen and the material. Normally two to six weighings were made during this period at various intervals. The fully saturated agings, on the other hand, required from one to 12 weeks to complete, again depending on specimen size and material. Specimens were removed from the aging cabinet and weighed between four and ten times at intervals of three to 14 days. After final removal from the humidity aging, the specimens were tested at both 72°F and at one of the elevated temperatures for which data on dry specimens were obtained. After removal from the humidity aging cabinet, the specimens were kept in a 72°F, 100% R.H. environment until tested (less than one-half day). During this period the specimens were exposed to ambient conditions for a maximum of about 45 minutes, during which time strain gages and gripping tabs were mounted on the specimens (interlaminar shear, short beam specimens of course, did not need this). The specimens tested at elevated temperature were placed in a preheated test oven and tested after a five to ten minute soak at the test temperature. The insertion of the specimens for elevated temperature testing into the grips in the test oven required less than one minute, during which time, the oven temperature fell about 50°F below its setpoint. The five to ten minute soak time was counted from the time the oven temperature returned to its

set point. The test oven required about five minutes to return to its set point. Hence, the humidity aged specimens which were tested at elevated temperature were actually in the test oven for a maximum of 10-15 minutes before testing. It is recognized that any elevated temperature soak of a "wet" composite produces a drying effect so that the test results are not actually representative of a truly "saturated" material. A compromise must be made, however, between the length of time required for a specimen to heat up to the test temperature and the rate at which a specimen dries out. Ideally, a steam test chamber would eliminate the requirement to make such a compromise. Few organizations have such a test chamber, however. The dryout which does occur during this period in the test oven results in a moisture concentration gradient through the thickness of the specimen, with the surfaces being "drier" than the interior. Several investigations[1-6] have conducted measurements on various composite materials and developed analytical expressions, based on diffusion studies, which can be used to compute moisture content profiles in "wet" laminates exposed to elevated temperature dryout conditions. No attempt was made in this work to measure the degree of moisture loss which occurred during testing of the "wet" specimens.

With the T300/V378A material, the effect of time-at-temperature (350°F, 177°C) before testing was examined on 90° compression specimens which had been humidity aged to saturation. Two specimens were tested after 10 minutes and three were tested after 5 minutes at 350°F (177°C). The 10-minute soak produced an average strength of 17.0 ksi (117 MPa), while the 5 minute soak produced an average strength of 20.1 ksi (138 MPa). This would seem to indicate that the specimens after 10 minutes may have been nearer to the test temperature than after 5 minutes. As far as the effect of drying out is concerned, the 5 minute values should have a higher retained moisture level than the 10 minute values.

3.5 LAMINATE MECHANICAL AND THERMOPHYSICAL PROPERTY CHARACTERIZATION

A total of eight types of mechanical property tests were performed on the composite materials evaluated during this program; tension, compression, flexure, inplane shear, interlaminar shear, tensile creep, tensile stress-rupture, and tensile-tensile fatigue. In addition, four thermophysical properties were measured; specific heat, thermal conductivity, coefficient of thermal expansion, and glass transition temperature. Tables 3-6 summarize the test matrices for the various types of tests conducted in this program, indicating the number of specimens tested for each test and test condition.

It can be observed from Tables 3 and 4 that the test matrices for the static and dynamic mechanical tests were not the same for each of the six materials tested. Two basic changes were made during the program, each of which imposed a different requirement for various numbers of certain tests and ply stacking sequence on the composite systems subsequently tested. These changes affected only the static tensile and the creep and fatigue tests.

It was determined early in the program that there was very little interest in or use for, creep and fatigue data on unidirectional 0° or 90° laminate orientations. Rather, it was determined there was considerably more interest in data on a multidirectional layup consisting of something on the order of 50% 0° plies, 45% ±45° plies, and 10% 90° plies. Even though the stacking sequence, and amount and direction of each ply orientation may be unique to a particular application, there was considerably more interest expressed in creep and fatigue data on any multidirectional layup corresponding roughly to the composition expressed above than in 0° or 90° unidirectional data. Consequently, it was decided to discontinue creep and fatigue tests on the unidirectional

TABLE 3

STATIC MECHANICAL PROPERTY TEST MATRIX

Test Type	Test Material					
	T300/AFR800	SiC/5506	HyE2034D	T300/V378A	HyE1076J	6535-1
0° Tension[1]	20	20	20	20	20	20
90° Tension[1]	20	20	20	20	20	20
±45° Tension[1]	20	20	20	20	20	20
(0/±45/90) Tension[2,5]	0	15	15	15	15	5
(0/±45/90) Tension with hole[3,5,8]	0	5	5	5	5	0
(0/±45/90) Tension[3,6]	0	0	0	0	0	5
(0/±45) Tension[3,7]	0	0	0	0	0	5
0° Compression[1]	20	20	20	20	20	20
90° Compression[1]	20	20	20	20	20	20
0° Flexure[1]	20	20	20	20	20	20
90° Flexure[1]	20	20	20	20	20	20
Inplane Shear[1]	20	20	20	20	20	20
Interlaminar Shear[4]	25	25	25	25	25	25

[1]Five tests each at four different test temperatures.
[2]Five tests each at three different test temperatures except for 6535-1, in which case all five were at room temperature.
[3]All five tests at room temperature.
[4]Ten tests at room temperature, five tests each at other three test temperatures.
[5]Twenty-ply with stacking sequence $(0,45,-45,0,0,-45,45,0,90,0)_S$.
[6]Twenty-ply with stacking sequence $(0,90,45,-45,0,0,-45,45,0,0)_S$.
[7]Sixteen-ply with stacking sequence $(0,45,-45,0,0,-45,45,0)_S$.
[8]Specimens had a 0.1935 inch (4.91 mm) hole in center of gage section.

TABLE 4

DYNAMIC AND TIME DEPENDENT MECHANICAL PROPERTY TEST MATRIX

Test Type	Test Material					
	T300/AFR800	SiC/5506	HyE2034D	T300/V378A	HyE1076J	6535-1
0° Tensile Creep/ Stress Rupture	18[1,4,6]	---	---	---	---	---
90° Tensile Creep/ Stress-Rupture	27[1,4,7]	---	---	---	---	---
±45° Tensile Creep/ Stress-Rupture	27	27	27	27	27	27
(0/±45/90) Tens. Creep/ Stress-Rupture[8]	---	27	27	27	27	6[1,3,5]
(0/±45/90) Tens. Creep/ Stress-Rupture[9]	---	---	---	---	---	6
(0/±45) Tensile Creep/ Stress-Rupture[10]	---	---	---	---	---	6
0° Tensile-Tensile Fatigue	30[2,4,6]	---	---	---	---	---
90° Tensile-Tensile Fatigue	30	---	---	---	---	---
±45° Tensile-Tensile Fatigue	30	30	30	30	30	30
(0/±45/90) Tensile-Tensile Fatigue[8]	---	30	30	30	30	15[2,4,5]
(0/±45/90) Tensile-Tensile Fatigue with hole[8]	---	15	15	15	15	---
(0/±45/90) Tensile-Tensile Fatigue[9]	---	---	---	---	---	15
(0/±45) Tensile-Tensile Fatigue[10]	---	---	---	---	---	15

[1]Three tests per stress level.
[2]Five tests per stress level.
[3]Two stress levels per test temperature.
[4]Three stress levels per test temperature.
[5]One test temperature.
[6]Two test temperatures.
[7]Three test temperatures.
[8]Twenty ply with stacking sequence $[0,45,-45,0,0,-45,45,0,90,0]_s$
[9]Twenty ply with stacking sequence $[0,90,45,-45,0,0,-45,45,0,0]_s$
[10]Sixteen ply with stacking sequence $[0,45,-45,0,0,-45,45,0]_s$

TABLE 5

THERMOPHYSICAL PROPERTY TEST MATRIX

Test Type	Test Temperature[1]			
	-67°F	72°F	T_3	T_4
Specific Heat	3	3	3	3
0° Thermal Conductivity	3	3	3	3
±45° Thermal Conductivity	3	3	3	3
0° Thermal Expansion	3	3	3	3
90° Thermal Expansion	3	3	3	3
±45° Thermal Expansion	3	3	3	3
Glass Transition Temp.[2] (dry)	3			
(wet)	3			

[1]The two elevated temperatures varied, depending upon the matrix resin.

[2]Dry refers to the as-fabricated composite condition, while wet refers to the condition of the specimen after it has reached an equilibrium weight gain during humidity aging at 160°F and 100% R.H.

TABLE 6

TEST MATRIX FOR STATIC MECHANICAL PROPERTY TESTS AFTER ELEVATED TEMPERATURE, HIGH HUMIDITY AGINGS

Test Type	Saturation Level			
	50%		100%	
	Test Temperature		Test Temperature	
	72°F	T_3^1	72°F	T_3^1
90° Tension	5	5	5	5
90° Compression	5	5	5	5
Interlaminar Shear	10	5	10	5

[1]This temperature varied depending upon the specific material.

0° and 90° orientations after completion of the work on the first material (T300/AFR800) and to substitute a multidirectional $(0,45,-45,0,0,-45,+45,0,90,0)_s$ orientation instead. In addition, some specimens with this orientation were also to be prepared with a hole in the center of the gage section to obtain an indication of notch sensitivity. The resulting test matrix was maintained for the next four materials which were characterized (SiC/5506, HyE2034D, T300/V378A, and HyE1076J). At that point another change was made.

During the testing of the multidirectional specimens discussed above, it was noted that the specimens exhibited delamination along the edges at the mid-plane during tensile loading. The point at which this delamination occurred was not recorded until the testing of the last material but occurred at a stress level well below that needed to fracture the specimen. In fact, during fatigue testing, these delaminations were usually dramatically evident long before final failure, or, in the case of some specimens, termination of the tests for residual strength determinations.

The reason for this delamination was the development of tensile stresses, at the free edge of the specimen, normal to the plane of the specimen. These stresses, in turn, arise because of the relative position of the various ply orientations, and the differences in the Poisson's ratio of these different plies. A seemingly innocuous shifting of the position of the 90° plies, or the elimination of them altogether, can drastically change the normal free-edge stress levels in specimens such as those under discussion. Several authors have addressed this issue in the literature and an analysis of the orientations tested in this program and discussion of the effects of alternative ply stacking sequences is presented in Appendix A.

As a result of this consideration, two additional multidirectional orientations besides the original $[0,45,-45,0,0,-45,45,0,90,0]_s$ orientation were added to the static and dynamic test matrix for the last material. In order to offset these additions, the number of tests to be run for each orientation was reduced, as indicated in Tables 3 and 4.

In addition to the number of specimens indicated in Tables 3-6, however, numerous instances were encountered where extra or replacement specimens had to be tested. These situations included instances where failures occurred in the tabbed grip areas rather than in the gage section, where instrumentation failures prevented full data acquisition or aborted a test, or simply occasions when anomalous results were obtained which dictated rechecking. Another source of extra specimen testing involved the creep and fatigue tests. In these tests it was found on several occasions that the stress levels initially selected produced premature failures. Consequently, the stress levels at which these tests were conducted were lowered and extra specimens tested so as to provide the full complement of results required. It will be noted in the summarized results in Section 4 that the number of specimens for which the average property values are reported varies from property to property. As discussed above, in some cases extra tests were conducted which raised the number of specimens above the original plan. In other cases, the behavior of the test specimen during test prevented the acquisition of one or more properties from that particular specimen. If, for example, the specimens underwent excessive elongation before failure, the strain gages were lost and ultimate elongation data were not obtained, even though strength, modulus, proportional limit, and Poisson ratio values were.

In the succeeding sections, descriptions of each of the test methods used to obtain the mechanical and thermophysical properties are presented. The summarized test results for each specific material system are presented in Section 4 and a complete tabulation of all of these test results is presented in Appendices D thru Q.

3.5.1 Tension

Tensile tests were conducted in general accordance with ASTM method D3039. The doubling tabs were a glass fabric/phenolic laminate material as discussed previously (Paragraph 3.2). The tensile tests were conducted at an extension rate

of 0.05 inch/minute (1.3 mm/minute) on an Instron Universal Testing Machine. All of the tensile strains were monitored with strain gages. This test procedure corresponds to ASTM method D3039 except for the tab materials. In the ASTM specification, the tab material called for is a non-woven 0°/90° Scotchply material 1/8 inch thick, while in this program a woven glass/phenolic material 1/16 inch thick was used satisfactorily.

Unidirectional 0° specimens were one-half inch (12.7 mm) wide while specimens with all other orientations (90°, ±45°, or multidirectional) were one inch (25.4 mm) wide.

The tensile proportional limits were determined with the understanding that the proportional limit should represent the point at which a significant departure from linearity in the slope of the stress-strain curve, presumably indicative of damage to the specimen, occurs. This can produce a substantially different value than if one were to simply take the point of first deviation from linearity. The first deviation of the stress-strain curve from linearity on the 0° fiber orientations actually occurred at roughly one-third of the ultimate stress but at this point the slope of the curve increased rather than decreased. It is generally conceded that this phenomena is due to the behavior of the reinforcing graphite fiber since the same behavior is noted when testing bare graphite fibers. Consequently, this is not felt to indicate damage to the specimen. No decrease in the slope of the stress-strain curve was in fact noted for most of the 0°, 90°, or multidirectional fiber orientations prior to failure except for the high temperature tests on the 90° fiber orientations, and for this reason the porportional limit is reported as equivalent to the ultimate strengths. On some of the high temperature tests with the 90° fiber orientations, on all of the ±45° fiber orientations and on all of the SiC/5506 specimens, a significant decrease in the slope of the stress-strain curves was observed below the ultimate strength. Whether this indicates the onset of real and significant damage, at least at the point of first departure, or simply the onset of nonlinear behavior, is a moot point.

The Poisson's ratio values were experimentally measured on all but the 90° fiber orientation. For this, it was computed from the relationship:

$$\nu_{21} = \nu_{12}\left(\frac{E_{22}}{E_{11}}\right), \text{ where}$$

ν_{21} = Poisson's ratio of a 90° fiber orientation,
ν_{12} = Poisson's ratio of a 0° fiber orientation,
E_{22} = Elastic modulus of a 90° fiber orientation, and
E_{11} = Elastic modulus of a 0° fiber orientation.

3.5.2 Compression

Compression tests were conducted in accordance with ASTM method D3410 except that the tab material was the same glass/phenolic material that was used in the tension tests. The compression tests were conducted at a speed of 0.05 inch/minute (1.3 mm/minute) on an Instron Universal Testing Machine. Prior to adoption by ASTM, this test method was widely referred to as the Celanese compression coupon test method.

Compression testing has traditionally been the subject of considerable controversy because of the various types of failure modes one can encounter. Not only can one obtain different failure modes with different types of test specimens and fixtures, but one can also experience different types of failure modes from the same type of test specimen and fixture. Inherent in the question of what is or is not a desirable failure mode is the requirement to avoid a gross specimen buckling-type of failure. This is different from what is called microbuckling, which consists of longitudinally oriented reinforcing fibers undergoing individual, localized buckling due to compressive stresses within the composite exceeding the capability of the resin matrix to support the fiber and maintain its axial alignment. Microbuckling is generally considered a legitimate compressive failure mode, while gross specimen buckling resulting from column instability is not. In order to eliminate the occurrence of column instability failures, specimens are designed with a slenderness ratio

sufficient to insure compressive failure before the load necessary to initiate column buckling is reached. Clark and Lisagor[7] recently examined three different compressive test methods for graphite/epoxy composites. The effects of specimen size, support arrangement, and method of load transfer were investigated. Their conclusion was that no single test fixture appeared to be universally adequate. Each of the three techniques studied exhibited the potential to provide reliable compressive properties data in certain instances. A method using what is designed as an IITRI (Illinois Institute of Technology Research Institute) fixture was found to provide the most consistent data for unidirectional and quasi-isotropic laminates while a face supported fixture provided the most consistent results for $(\pm 45/\mp 45)_s$ specimens.

The compression test described in D3410 is similar to that described in Clark and Lisagor using the IITRI fixture. The principle difference is that the IITRI fixture utilizes flat wedge type grips while the grips in D3410 are conical wedges. One objection to this test method which has been raised is that the mated conical surfaces make line rather than surface contact during testing and that this produces frictional and alignment problems which affect the recorded results.[8] Our experience has been that the frictional problems are minimal except when testing at reduced temperatures. In this case, frost accumulates on the fixture and the sliding surfaces do not slide freely, producing some spurious load recordings although use of a low temperature lubricant reduces the problem substantially. Misalignment has proven to be a problem, however. Although the specimens were designed to eliminate buckling instability, it has been found that buckling sometimes occurred anyway at stresses between 75% and 100% of ultimate. This behavior was indicated by strain reversals on the load-strain curve and by nonsymmetrical deformations present in failed specimens. The misalignment is induced by the nonuniform seating of the fixture cone in the conical socket. This non-uniform seating, in turn, results from the distortion imposed upon the split cone by the thickness of the specimen. The

principal advantage of the IITRI flat-wedge fixture over that called for in D3410 is the elimination of the wedge-socket seating and alignment problem.

We have found, however, that increasing the specimen thickness does reduce the amount of buckling which occurs with the conical wedge fixture of D3410. Apparently, the increased column stability obtained with greater thickness more than offsets alignment problems due to the increased distortion of the split cone produced by the specimen thickness. An increase in specimen thickness from 0.080 inch (2.0 mm) to 0.110 inch (2.8 mm) resulted in a reduction of the incidence of specimen buckling from 60% to only 15% of the total number of specimens tested, and the bulk of these remaining cases of buckling occurred at -67°F (-55°C), where frictional problems with the sliding surfaces are greatest. Consequently, it is believed that the use of sufficiently thick specimens, with a lubricated surface at temperatures below freezing, makes this test method quite satisfactory for specimens made with unidirectional tape prepreg. Another advantage to using this test method is that the data will be directly comparable to results obtained by other investigators and on other materials since the technique is widely used in the aerospace industry.

3.5.3 Flexure

Most of the flexural testing in this program was conducted using the four-point loading method described in the January 1971 issue of the Advanced Composite Design Guide.[9] In this volume, a three-point technique is recommended for 0° fiber orientations and a four-point technique for 90° fiber orientations. It has been observed, however, that with a three-point loading scheme, one frequently encounters undesirable failure modes under the loading nose and subsequent anomalous strength values on high modulus composite materials with a 0° fiber orientation. For this reason, the four-point method was used, with a few exceptions, for both fiber orientations in this program. The reason for the exceptions is that shear failures were obtained on some of the materials, particularly

at elevated temperatures, when the four-point method was used. The ratio of shear stress to flexural stress is greatly reduced in three-point loading versus four-point loading, thereby reducing the likelihood of shear failure before flexural failure.

The four-point loading method described in the Design Guide is essentially identical to the ASTM flexure test (D790) except for the testing speed and the locations of the load application points in four-point loading. The Design Guide recommends a blanket testing speed of 0.05 inch/min. (1.3 mm/min.) while D790 recommends a speed which is dependent upon specimen thickness and span-to-thickness (L/d) ratio. For the thicknesses used in this program and a 32:1 L/d ratio, D790 calls for a testing speed of 0.11 inch/minute (2.8 mm/minute) for three-point loading and 0.13 inch/minute (3.3 mm/minute) for four-point loading, although a maximum variation of up to ±50% above or below these speeds is permitted. The spacing of the upper loading noses the Design Guide method is equal to one-half the span between the lower supports, while in D790 the spacing of the upper loading noses is equal to one-third of the span. The major difference is that the ratio of shear stress to flexural stress is 33% greater in the Design Guide arrangement than in the D790 arrangement.

While a wide range of specimen thickness is permissible according to D790, recent studies at Rockwell[10] on graphite/polyimide laminates indicated that at both room temperature and 600°F (316°C) flexural strength decreased with specimen thickness in the 0.06-0.10 inch (1.5-2.5 mm) thickness range. Our specimens were 0.070-0.076 inch thick on all of the materials we tested except for the SiC/5506, in which case the specimens were 0.100 inch thick. All of the tests were conducted at a crosshead speed of 0.05 inch (1.3 mm)/minute and at a L/D ratio of 32:1.

3.5.4 Inplane Shear

The inplane shear data were computed from longitudinal and transverse load-strain measurements on a uniaxial

tensile test on a $\pm 45°$ crossplied laminate. This method is in accordance with ASTM D3518.

The inplane shear stress-strain curve is obtained by a point-by-point conversion of the tensile load and strain data. This converts tensile stress-strain ($\sigma-\varepsilon$) information to shear stress-strain ($\tau-\gamma$) data. The shear modulus (G) can then be obtained from the initial slope of the $\tau-\gamma$ curve. The shear modulus can also be computed directly from the tensile elastic modulus (E) and Poisson's ratio (ν) of the $\pm 45°$ specimen using the basic relationship,

$$G = \frac{E}{2(1+\nu)} .$$

3.5.5 Interlaminar Shear

Interlaminar shear is another property for which no simple or problem-free test exists. The most widely used test is the short beam shear test described in ASTM D2344. Another test is the opposed double notch specimen with side supports and a third test utilizes torsional loading of a rod but requires special fixturing. Each of these tests is subject to certain objections. The notched specimen is known to have high stress concentrations at the notch edges. The torsional specimen is not felt to have a straight line stress distribution at the higher stresses even though this assumption is made in computing the failure strength. The short beam specimen produces high strength values because of its short span and the compressive stresses introduced by the loading nose and supporting points. The stress concentrations and complex stress states present in the short beam specimen are aggravated by the use of a thinner specimen than that illustrated in D2344, a practice common to nearly everyone who conducts this test. Whitney[11] has found that short beam shear specimens tested at a 4:1 span-to-thickness ratio produce higher strengths in 0.125 inch (3.2 mm) thick specimens than in the 0.250 inch (6.4 mm)

thickness recommended by D2344. He further feels that common failure modes for specimens of this type, particularly in thinner sections, is not normally in interlaminar shear at the midplane, but rather near the top of the specimen and due to a complex interacting stress state. An alternative test method for interlaminar shear, which has produced clear mid-plane shear failures at stress levels near those achieved with a 0.250 inch (6.4 mm) D2344 specimen, has been investigated by Whitney. It consists of a four-point bending test with a 16:1 span-to-thickness ratio for graphite composites. The upper loading noses are spaced half as far apart as the two lower supports. It is felt that the mid-plane stress state is simpler and more nearly pure shear on this type specimen than on the short beam specimen and that so long as the ultimate failure mode is indeed a mid-plane shear failure, one generates realistic shear strength values. The only problem which has been encountered with this test is that ductile matrices (i.e., polysulfone) produce tensile failures on the lower surface before shear failure occurs at the mid-plane.

In spite of the admitted shortcomings with the short beam shear test using specimens thinner than 0.250 inch (6.4 mm), it was decided in this program to use a thin short beam shear specimen for interlaminar shear because it would better enable the generated data to be compared to other composite material data.

3.5.6 Tensile Fatigue

Fatigue tests were conducted on the fiber orientations indicated in Table 4. Where 30 specimens are indicated, 15 tests were conducted at room temperature and 15 at elevated temperature. Where only 15 specimens are indicated, all were conducted at room temperature. Each group of 15 was subdivided into three groups of five, each of which was tested at a different maximum stress level. Five replications were run for most conditions. In some cases, however, the 15 specimens were distributed differently due to an effort to avoid lifetimes that were either too short (<5,000 cycles) or too long (>$2x10^6$

cycles). In these cases, data were obtained at more than three stress levels and less than five specimens were tested at some of the stress levels. The same type of specimen was used for fatigue as was used for tensile tests. All of the tests were constant load amplitude at a frequency of 10 Hz with the minimum stress equal to one-tenth the maximum stress. The specimens were cycled to a maximum of 10^7 cycles, at which time, if no failure had occurred, they were removed and tested for residual tensile properties. All residual property tests were conducted at 72°F, regardless of the temperature at which the specimens were fatigue loaded.

The fatigue lifetimes (number of cycles) reported in Tables 17, 31, 44, 58, 71, and 86 represent log-mean values of the individual specimen values for each stress level. Similarly, the straight lines plotted through the individual data points in Figures 20, 21, 22, 38, 39, 40, 55, 56, 57, 71, 72, 73, 87, 88, 89, 104, and 105 represent a least squares fit of the maximum cyclic stress versus log (cycles to failure), with maximum cyclic stress considered the independent variable (x) and log (cycles to failure) considered the dependent variable (y) in the least squares linear equation $y = a + bx$.

The fatigue tests were carried out on MTS, closed-loop, electrohydraulic, servo-actuated testing machines. Specimen gripping was by means of wedge-type Instron grips. The grips are locked into place on the loading ram and load cell to insure constant alignment. Axial and concentric alignment of the ram and load cell was verified with a dial gage to within 0.001 inch and grip alignment was insured by the use of a specially machined straight aluminum bar in place of a specimen. Spacers were utilized to center the one-half-inch wide 0° specimens in the one-inch wide jaws and periodically, a specially strained gaged specimen was placed in the grips and the strains on opposite sides and edges monitored during loading to insure that eccentric loading was held below 1 percent.

Both room and elevated temperature tests were conducted in Instron circulating air environmental test cabinets. Temperature control in elevated temperature tests was maintained with Instron oven proportional temperature controllers with chromel/alumel thermocouples positioned directly adjacent to the specimen gage section.

An additional thermocouple was taped against the specimen surface in the center of the gage section to monitor specimen temperature. This was done because fatigue loading of specimens with off-axis ply orientations results in the generation of internal heat due to large repetitive deformations. Specimen surface temperatures as much as 25-30°F (14-17°C) greater than surrounding air temperature have been observed on ±45° layups on the materials tested in this program. On the multidirectional layups (0/+45/90), specimen surface temperatures as much as 60°F (33°C) above surrounding air temperature have been measured.

3.5.7 Tensile Creep

Creep tests were conducted on the fiber orientations indicated in Table 4. Where 18 specimens are indicated, nine tests were conducted at each of two elevated test temperatures. Where 27 specimens are indicated, nine tests were conducted at each of three test temperatures (room temperature and two elevated temperatures). In each of these cases the nine-specimen groups were further subdivided into three groups of three specimens each and each of these tested at a different stress level. Where only six specimens were indicated, all tests were conducted at room temperature. Each of these groups of six were subdivided into two groups of three and these were then tested at two different stress levels.

The same specimen design used in tensile testing was used for the creep tests. Creep strain measurements were recorded using one-inch long strain gages and were carried out to a maximum of 500 hours, at which time, if a specimen had not

fractured, it was unloaded and creep recovery measurements recorded for a period of three hours. Each of these surviving specimens was then tested for residual tensile properties at 72°F. It will be noted that the creep recovery data are not included in the tabulated summaries of Section 4. The recovery data are presented, however, in Appendix J.

The creep tests were carried out on Arcweld creep frames. Each frame has the capacity, through a 20:1 counter-balanced lever arm, of putting loads of up to 12,000 lbs. on the test specimen. Each frame is also equipped with an electric timer and automatic shutoff switch, which monitors the total creep time as well as time to failure. Each frame also has an electrically driven load weight elevator and self-aligning couplings.

Specimen gripping was by means of serrated face jaw type grips. The 90° and $\pm 45°$ orientations were held in grips where the serrated grip faces were tightened against the loading tab material by means of set screws. The 0° and $(0/\pm 45/90)$ orientations were held in wedge-type jaw grips.

Elevated temperature creep tests were conducted in short tube-furnaces (Figure 3).

Figure 3 . Short Tube-Furnace Used in Elevated Temperature Creep Tests.

With these short furnaces (four inches long and one and one-half inches diameter tube), only the gage section of the specimen was in the heated zone. Temperature control on these tube furnaces was maintained with a thermistor actuated, time-proportioning controller employing a zero crossover switching triac, and transient fluctuations were less than $\pm 3°F$ around the setpoint. The temperature controlling thermistor was mounted on the side of the one inch wide test specimens and the specimen centered in the uniform temperature region of the furnaces. Additionally, three thermocouples were attached to the specimen, one next to the thermistor and the other two at a distance of one-half inch on either side of the thermistor to insure that the thermistor was at the optimum location. Figure 4 presents a typical temperature profile of the tube furnaces used for these tests. It can be seen that the central two-inch portion of this type tube furnace maintains a relatively "flat" temperature profile which is within $\pm 5°F$ of the setpoint. Specimens were stabilized at the test temperature for at least two hours before the load was applied.

Strain measurements were obtained from one-inch long strain gages mounted on the specimen surfaces and wired into a Vishay model P-350A digital strain indicator through a Vishay model SB-1 ten-channel switch and balance unit. Compensation for thermal expansion during elevated temperature tests was achieved by utilizing a compensating gage on a short section of unstressed specimen material taped to the gage section of the actual test specimen. The output from this compensating gage was fed into an adjacent leg of a half-bridge circuit.

Many of the creep specimens were tested in a series loading arrangement of up to three specimens in order to increase the rate of data acquisition. Figure 5 illustrates such an arrangement. In cases where one of the specimens in a series broke prior to the 500-hour termination point, the remaining specimens were replaced and new tests conducted.

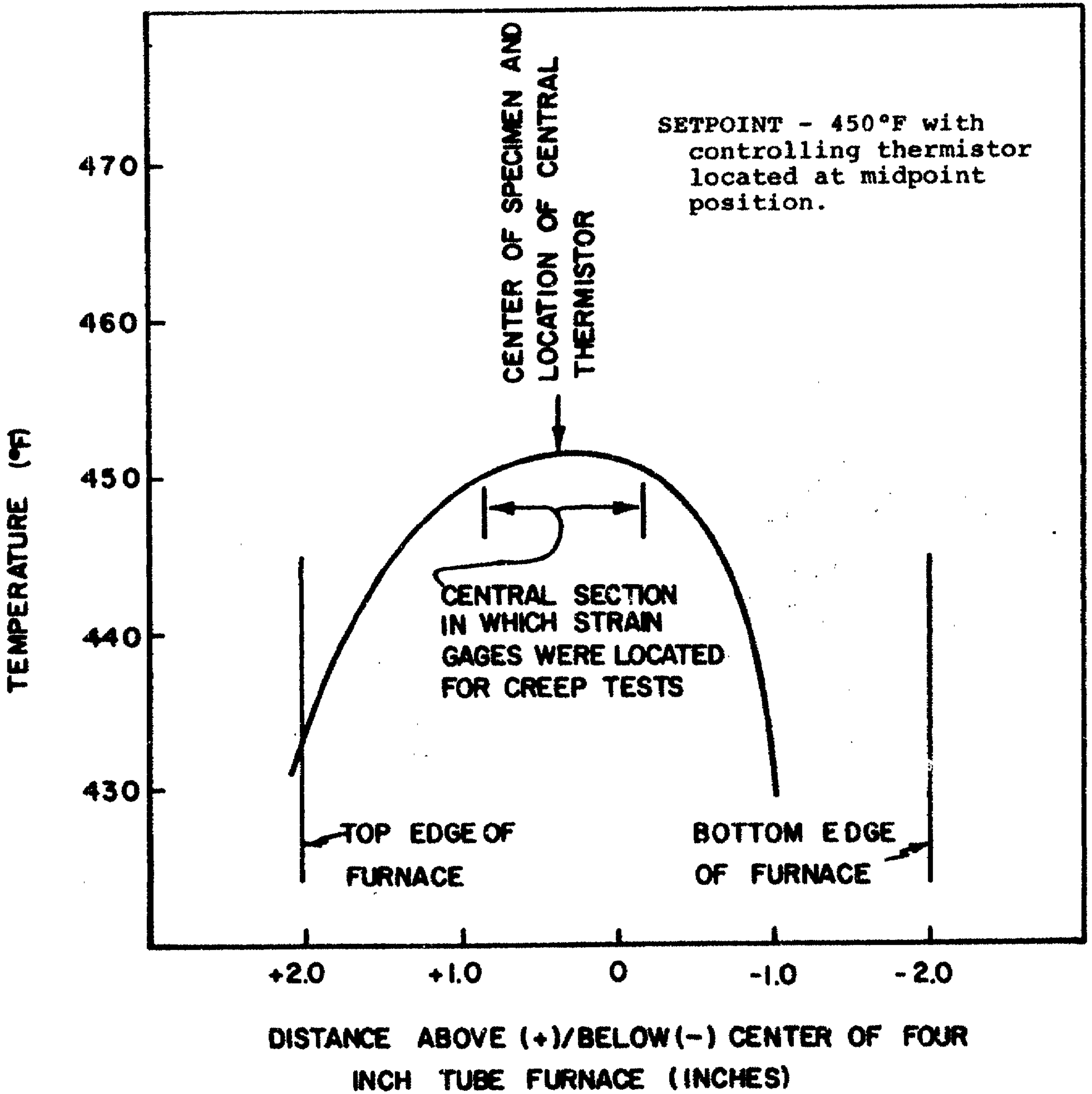


Figure 4. Typical Temperature Profile of Four-Inch Tube Furnaces.

Figure 5. Stacking Arrangement for Testing Three Creep Specimens Simultaneously.

It will be noted in the tables in the text, as well as in Appendix J, that many creep specimens failed on loading even though the applied stress was less than the strength obtained in the static test at the same temperature. The only factor to which this can be attributed is that the creep load was applied at a considerably more rapid (though not instantaneous) rate than the load applied during the static test. The reason for this is that the load pans on the creep frames are raised and lowered by a motor driven elevator, which operates much more rapidly than the 0.05 inch (1.3 mm)/minute rate utilized during static testing.

3.5.8 Tensile Stress Rupture

Stress rupture data were obtained from the same specimens used for the creep tests, the only difference being that time-to-failure rather than strain as a function of time was the measured variable of interest.

3.5.9 Specific Heat

Specific heat was measured with a Perkin-Elmer DSC-2 differential scanning calorimeter. This technique compares the rate of heat input required to maintain a constant rate of temperature rise in an unknown sample to that required to maintain the same rate of temperature rise in a known reference material.

The tests conducted in this program utilized sapphire as a reference material for tests at room temperature and above and benzoic acid for subambient tests. Samples consisted of a single ply of cured prepreg material. A small (10 mg maximum) circular piece was cut from the single ply of material. The test was conducted by equilibrating both sample and reference material at a temperature about 25°C (45°F) below the temperature at which a specific heat value is desired. Both are then heated at a rate of 10°C (18°F)/min. to a temperature about 25°C (45°F) above the measurement temperature and re-equilibrated at this new temperature.

Relative heat capacity values were measured on the ordinate scale of a strip chart recorder for both the sample and reference material. Specific heat of the sample is computed from:

$$Cp,s = \left(\frac{W_r}{W_s}\right)\left(\frac{D_s}{D_r}\right) Cp,r$$

where:

Cp,s = specific heat of the sample
Cp,r = specific heat of the reference

W_s = weight of sample
W_r = weight of reference

D_s = displacement of sample curve from baseline
D_r = displacement of reference curve from baseline

The displacement of the respective curves from the baseline are illustrated in Appendix L, which also illustrates the treatment of a sloping baseline and a sample calculation.

3.5.10 Coefficient of Thermal Expansion

Thermal expansion was measured using a Perkin-Elmer Model TMS-2 Thermomechanical Analyzer (TMA). The TMA instrument has been specially modified to isolate it from external vibrations and has been fitted with a special chamber to house the sensitive electronic components in an isothermal environment. With these modifications, the instrument is capable of coefficient of thermal expansion (CTE) measurements as low as $10^{-7}/°C$. Without these modifications, at least one order of magnitude sensitivity is lost.

The instrument basically measures the change in one dimension (i.e., length) of a material, as a function of temperature. For low CTE materials (less than $10^{-5}/°C$) it is important for the test sample to have its ends carefully machined to a flat and parallel condition. A free-floating probe, attached to a linear variable differential transformer (LVDT), rests on the test sample, contained within a stationary sample tube. A furnace can be raised or lowered around the sample tube. A thermocouple is located as close as possible to the sample for temperature measurement independent of the furnace control.

The test is time-consuming since the sample and system must be brought to thermal equilibrium before the measurement is made. This requires from one to seven hours, depending on the temperature level and sensitivity level at which the test must be conducted. For materials with low CTE values, the system must be calibrated by conducting a run without a sample. The change in probe position must be subtracted from that measured with the sample in place in order to obtain an accurate value for the sample alone. This is necessary because of sensitivity of mechanical linkages in the system to temperature changes. As CTE increases this component becomes negligible.

The CTE values reported in Section 4 for the various materials were obtained by equilibrating the sample at a temperature 40°C below the temperature at which a value

was desired, and heating it to an equilibrium condition at a temperature 40°C above the desired temperature. The difference in recorded probe position for the two equilibrium positions is converted to a change in sample length (ΔL) and for the 80°C temperature change (ΔT), a CTE value is computed from the standard equation:

$$\alpha = \frac{\Delta L}{L_O \Delta T}$$

where: α = CTE
ΔL = change in sample length
L_O = original sample length
ΔT = change in temperature.

3.5.11 Thermal Conductivity

Thermal conductivity was measured in the direction normal to the laminate surface for both unidirectional and ±45° fiber orientations. A comparative technique was employed in which the sample is sandwiched between two identical reference materials of known conductivity. These, in turn, are held firmly between a heater and a heat sink. The heat flux through this stack establishes a temperature gradient which is measured with thermocouples placed on the upper and lower surfaces of both reference plates and the specimen plate in small precisely machined grooves. Radial heat flow to and from the test stack is minimized with a cylindrical guard heater in which a linear temperature gradient, closely matching that of the test stack, is maintained. A Dynatech Model TCFCM-N20 thermal conductivity instrument was used for these measurements. Data points were taken at approximately equal temperature intervals over the range of interest and a "best-fit" curve (or straight-line) plotted through these data points. The reported values in Section 4 were taken from these plotted curves at the specific temperatures. The maximum scatter of the individual data points on either side of the plotted curves was about ±15% of the reported values.

3.5.12 Glass Transition Temperature

Glass transition temperatures (T_g) were measured with a DuPont Model 981 Dynamic Mechanical Analyzer (DMA).

A schematic diagram of the DMA system is shown in Figure 6. The mechanical portion of the system consists of two parallel balanced sample support arms made of stainless steel, and free to oscillate around flexure pivots. The arm-pivot system is constructed in such a way to give it a very low natural free oscillating frequency (less than 3 Hz).

The sample, in the form of a rectangle, is clamped between the arms as shown to form a compound resonance system, the resonant frequency of which is dependent almost entirely (because of the low natural resonant frequency of the arm-pivot system) on the configuration and modulus of the sample. In oscillation, the sample is deformed as illustrated by the geometry in Figure 7. In the equilibrium position, before oscillation, the sample, the centerlines of the two arms, and an imaginary line connecting the centers of the two flexure pivots form a rectangle represented by the broken lines.

If the compound resonance system is deflected away from the equilibrium position to a new position (represented by the solid lines in Figure 7). the two ends of the sample remain parallel to each other and perpendicular to the arms. The center of gravity of the sample and of the arms, however, translate to new positions. During each cycle the sample is subjected to an alternating flexural deformation. The solution for the dynamic equation of motion for the system gives the relationship between Young's modulus and frequency:

$$E = \frac{(4\pi^2 f^2 J - K)}{2W\left[\frac{L}{2} + D\right]^2} \left[\frac{L}{T}\right]^3, \qquad \text{where}$$

E = Young's modulus (Pa),

f = DMA frequency (Hz),

J = Moment of inertia of arm ($kg \cdot m^2$),

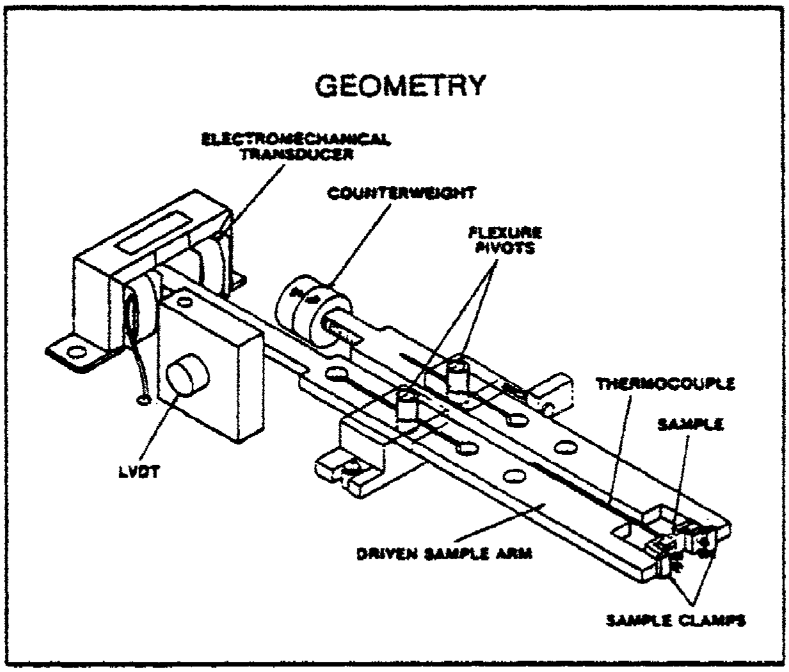


Figure 6. Test Geometry for DuPont 981 Dynamic Mechanical Analyzer (DMA).

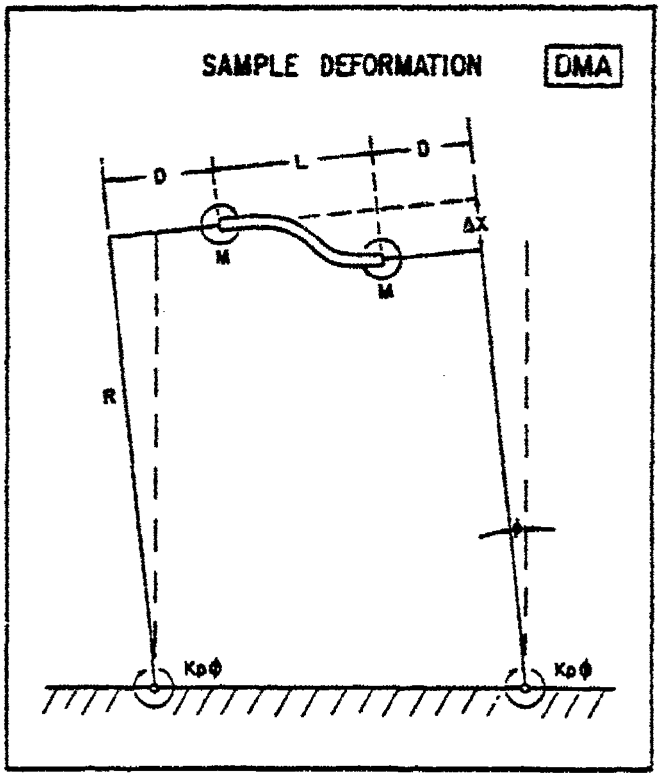


Figure 7. Sample Deformation in DuPont 981 DMA Apparatus.

K = Spring constant of pivot (N·m/rad),

D = Clamping distance (m),

W = Sample width (m),

T = Sample thickness (m), and

L = Sample length (m).

Sample loss factor, η, is calculated from

$$\eta = \frac{CV}{f^2}, \quad \text{where}$$

V = DMA Damping Signal (mV),

f = DMA Resonant Frequency (Hz), and

C = System Constant ($\sim$0.25 Hz^2/mV).

To make a measurement, a sample of known dimensions is clamped between the two sample arms. The sample-arm-pivot system is oscillated at its resonant frequency by an electromechanical transducer. The frequency and amplitude of this oscillation are detected by an LVDT positioned at the opposite end of the active arm. The LVDT provides a signal to an electromechanical transducer, which in turn keeps the sample oscillating at constant amplitude. Sample resonant frequency (measured to 0.01 Hz) and damping (measured to 0.1 dB) signals are supplied to the temperature programmer/recorder where they are graphically recorded as a function of the measured sample temperature or time. Young's modulus for the sample can be obtained from resonant frequency by using the relationship in the Equation and loss factor can be obtained from the Equation.

In this program, T_g values were defined as that temperature at which the loss modulus is maximum. Loss modulus, in turn, is defined as

$$E' = \frac{E}{\eta}, \quad \text{where}$$

E' = loss modulus,

E = Young's modulus (from the first equation), and

η = loss factor (from the second equation).

Specimens were run both "dry" and "wet", the "wet" condition implying that the sample was humidity aged at 160°F and 100% R.H. to an equilibrium weight gain prior to the determination. Unfortunately, there was no way to prevent the "wet" specimen from drying somewhat during the test. Hence, the specimen was no doubt at some moisture content less than saturation when the indicated T_g was observed. Nonetheless, the "wet" values were lower than the "dry" values in five of the six cases, indicating a definite softening due to whatever moisture level still remained in the sample. In the one exception, the T300/V378A system, the composite gained weight during moisture aging very rapidly compared to the epoxy systems, although the total weight gain was only slightly higher. It would not be unreasonable to assume that, when heated, this material would lose absorbed moisture much more rapidly than the epoxy systems also. This, coupled with the fact that the T_g value for the V378A resin is substantially higher than those measured for epoxies (by 200-300°F) would make it reasonable to speculate that the so-called "wet" V378A sample has completely dried out by the time its T_g is reached, thereby resulting in identical T_g values being determined for both the "dry" and "wet" samples.

SECTION 4

SUMMARIZED COMPOSITE DATA

This section presents tabulated summaries of all the data generated for each composite system evaluated during the program. Also presented are the averaged stress-strain, creep, and fatigue S-N curves for each of the systems.

In addition to the summarized data and averaged mechanical property curves, pertinent observations made during the characterization of each material are discussed.

4.1 T300/AFR800

The matrix resin in this system was developed under USAF contract by the Aerotherm Division of Accurex Corporation.[12,13] The objective was "to achieve state-of-the-art performance (350°F [177°C]) from graphite fiber reinforced composites coupled with prolonged prepreg flow life under ambient shop conditions." This was basically achieved by utilizing aromatic diamine curing agents with "attenuated reactivity and limited solubility in the resins."

The resin was prepared according to the Aerotherm recipe by Hexcel (Dublin, California) and was also prepregged by Hexcel.

Tables 7 through 18 present the data generated for this graphite-epoxy composite system. Figures 8 through 22 illustrate the stress-strain, fatigue, and creep behavior of this material as well as the effects of humidity aging upon selected composite properties.

TABLE 7

PROCESSING CONDITIONS FOR T300/AFR800 COMPOSITE LAMINATES

Composite Processing Information	
Material System - T300/AFR800 Fiber - T300/ Matrix - AFR800[1] Maximum Rated Temperature - 350°F	Graphite/Epoxy Prepreg by - Hexcel
Laminate Processing Schedule	
Layup Procedure: The prepreg was stored in a closed wrapper at room temperature. Prepreg was removed from wrapper and plies cut to desired size using a razor knife. Plies were stacked in the desired sequence (release paper removed from each ply). The stack was placed in the autoclave according to the layup system illustrated in Figure 8. The corprene edge dam serves to restrict fiber flow.	
Cure Schedule: Apply full vacuum and hold for one hour at room temperature. Heat to 275°F in 60 $\pm$ 5 minutes under at least 10 inches Hg vacuum. Hold at 275°F for 50 minutes less than the gel time.[2] Apply 75 psi and vent vacuum at the end of this hold time. Heat to 325°F in 30 $\pm$ 5 minutes. Hold at 325°F for four hours. Cool under pressure to 120°F.	
Postcure Schedule: The panels were placed, unrestrained, in an oven at room temperature. The oven was brought to 375°F at rate of about 5°F/min. After a four-hour hold at 375°F, the oven was turned off. When the oven was cooled to near room temperature, the panels were removed.	

[1] Resin development and composition is described in AFML-TR-77-158.

[2] This cure schedule is given in AFML-TR-77-158, where it is stated that the key processing parameter is the point of pressure application at the 275°F hold temperature. This, in turn, depends upon the gel time. We have found that gel time has depended upon the method used for the measurement. The Hercules method (HD-SG-2-6006C, para. 5.5), in which a prepreg sample is rolled up in aluminum foil, gave a gel time of 140 minutes. The Fiberite method (Fisher-Johns melting point apparatus) gave a gel time of 87 minutes.

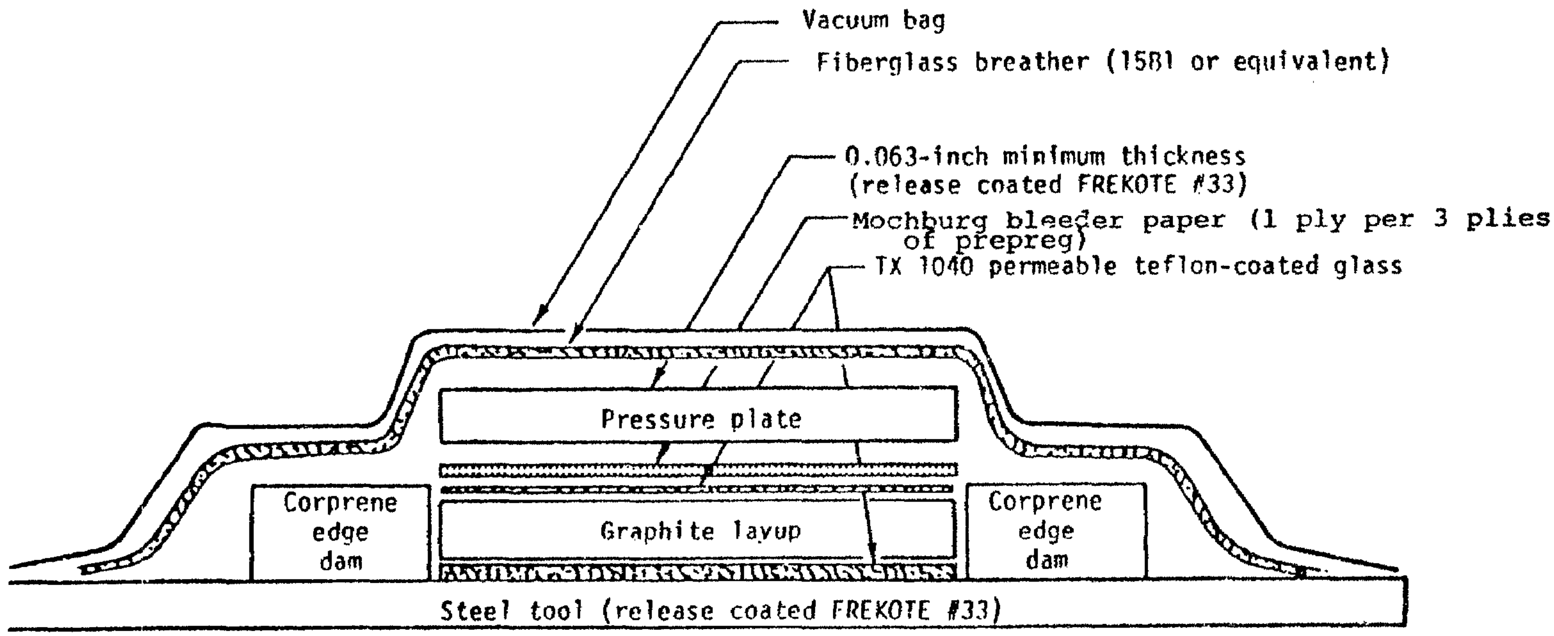


Figure 8. Layup System for AFR-800 Laminates.

TABLE 8

PREPREG AND COMPOSITE PHYSICAL PROPERTIES

Composite Physical Property Information				
Material System - T300/AFR-800 Fiber - T300 Matrix - AFR-800 Maximum Rated Temperature - 350°F			Graphite/Epoxy Prepreg by - Hexcel	
Prepreg Physical Properties				
(Property)	(Stnd.Dev.)	(Range)	(Test Method)	(Ref.)
Volatile Content- 0.11%		0.07-0.18	HD-SG-2-6006C(5.1.2)	
Resin Content- 40.1%		39.1-41.5	HD-SG-2-6006C(5.2)	
Resin Flow- 15.51%[2]		15.49-15.53	HD-SG-2-6006C(5.3.2B)	
No. of Rolls Involved- 1				
No. of Batches Involved- 1			Hercules test methods	
Laminate Physical Properties[1]				
	(Stnd.Dev.)	(Range)	(Test Method)	(Ref.)
No. of Panels- 36				
Fiber Content- 69.1% by vol.	3.7	61.1-77.0	Acid Digestion AFML-TR-67-243	
Resin Content- 26.6% by wt.	2.8	23.5-33.1	Acid Digestion AFML-TR-67-243	
Void Content- 0.2% by vol.	0.8	0-4.4	D2734	ASTM
Laminate Sp. Gr.- 1.60	0.04	1.54-1.71	D792	ASTM
Fiber Sp. Gr.- 1.70	As reported by manufacturer.			
Matrix Sp. Gr.-1.24	As reported by manufacturer.			
Thickness per ply-0.0052 inch			---	---

[1]The properties reported here represent averages for all panels of this material used throughout the program.

[2]After 30 days storage at R.T., flow was remeasured and found to have increased to 19.32%.

TABLE 9

TENSILE PROPERTIES OF T300/AFR800 COMPOSITE LAMINATES

Composite Material Properties

Material System - T300/AFR 800 Fiber - T300 Matrix - AFR 800 Maximum Rated Temperature - 350°F(177°C) Resin Content - 25.0% by wt. Fiber Content - 67.6% by vol. Void Content - ~0% by vol. Thickness of each type specimen: 0° - 6 ply	Prepreg by - Hexcel Laminate Sp. Gr. - 1.61 Nominal, Ply Thickness - 0.0051 inch No. of panels from which specimens were tested in this table - 10 ; 90° - 15 ply	Graphite/Epoxy

TENSION: 0°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F (177°C)
F_x^{tu} [ksi](MPa)	[186.7] (1286)	[179.6] (1237)	[193.9] (1336)	[173.5] (1195)
Stnd.Dev. [ksi](MPa)	[15.8] (109)	[17.0] (117)	[17.4] (120)	[21.0] (145)
Range [ksi](MPa)	[172.2-212.1] (1187-1461)	[169.6-205.6] (1169-1417)	[174.3-213.3] (1201-1470)	[159.7-200.9] (1100-1384)
No. of Specimens	5	5	5	5
F_x^{tpl} [ksi](MPa)	[186.7] (1286)	[179.6] (1237)	[193.9] (1336)	[173.5] (1195)
Stnd.Dev. [ksi](MPa)	[15.8] (109)	[17.0] (117)	[17.4] (120)	[21.0] (145)
No. of Specimens	5	5	5	5
E_x^t [Msi](MPa)	[20.87] (143,800)	[18.69] (128,800)	[20.40] (140,600)	[19.87] (136,900)
Stnd.Dev. [Msi](MPa)	[0.49] (3380)	[0.98] (6750)	[0.44] (3030)	[0.43] (2960)
No. of Specimens	5	5	5	5
ϵ_x^{tu} [µin/in](µcm/cm)	8520	8700	9040	8380
Stnd.Dev.	572	648	620	870
No. of Specimens	5	5	5	5
ν_{xy}^t	0.319	0.312	0.307	0.355
Stnd. Dev.	0.010	0.034	0.022	0.037
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3039			

TENSION: 90°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F (177°C)
F_y^{tu} [ksi](MPa)	[4.69] (32.3)	[4.58] (31.6)	[4.68] (32.2)	[5.42] (37.3)
Stnd.Dev. [ksi](MPa)	[1.27] (8.75)	[1.01] (6.96)	[0.50] (3.45)	[0.67] (4.62)
Range	[2.80-6.31] (19.3-43.5)	[3.20-5.75] (22.0-39.6)	[4.33-5.56] (29.8-38.3)	[4.80-6.53] (33.1-45.0)
No. of Specimens	5	5	5	5
F_y^{tpl} [ksi](MPa)	[2.89] (19.9)	[4.17] (28.7)	[3.79] (26.1)	[2.86] (19.7)
Stnd.Dev. [ksi](MPa)	[1.84] (12.7)	[0.65] (4.48)	[1.21] (8.33)	[1.17] (8.06)
No. of Specimens	5	5	5	5
E_y^t [Msi](MPa)	[1.63] (11,230)	[1.48] (10,200)	[1.36] (9370)	[1.19] (8200)
Stnd.Dev. [Msi](MPa)	[0.07] (480)	[0.04] (276)	[0.04] (280)	[0.0[illegible]] (551)
No. of Specimens	5	5	5	[illegible]
ϵ_y^{tu} [µin/in](µcm/cm)	2870	3110	3510	4910
Stnd. Dev.	760	720	330	897
No. of Specimens	5	5	5	5
ν_{yx}^t	0.025[1]	0.025[1]	0.020[1]	0.021[1]
Test Method Reference	ASTM D3039			

[1]Computed using elastic modulus and longitudinal Poisson's ratio.

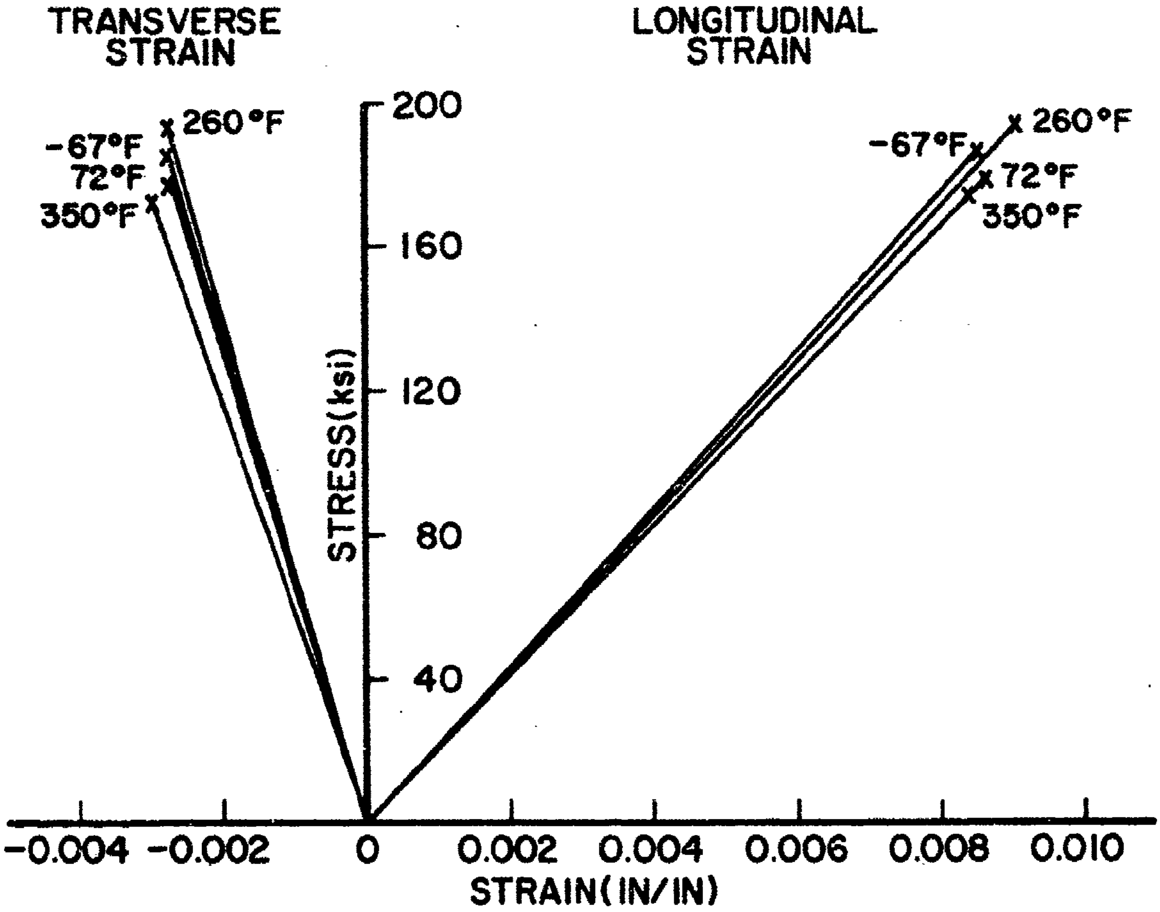


Figure 9. Tensile Stress-Strain Curves for Unidirectional T300/AFR800 Composite Laminates: 0° Fiber Orientation.

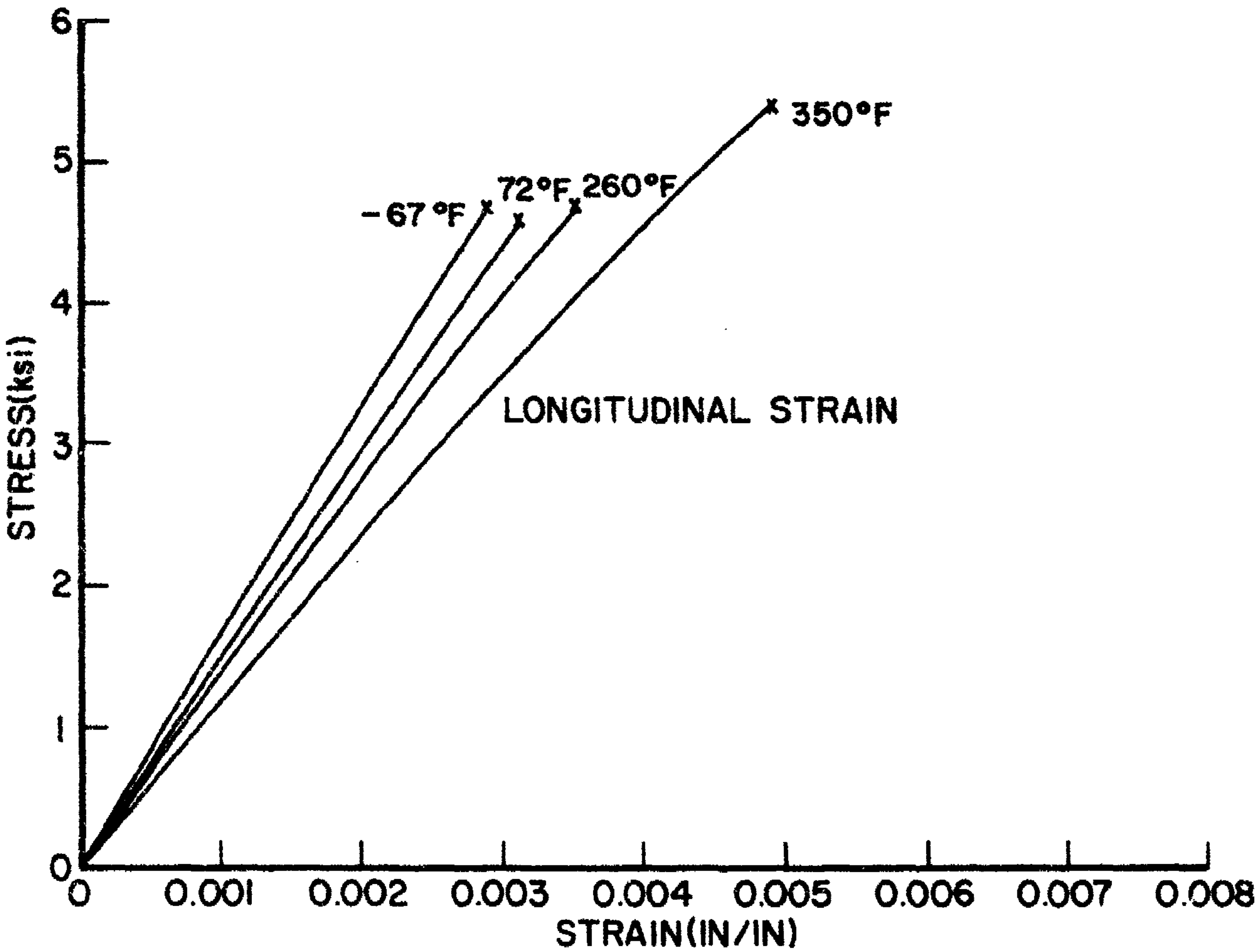


Figure 10. Tensile Stress-Strain Curves for Unidirectional T300/AFR800 Composite Laminates: 90° Fiber Orientation.

TABLE 10

TENSILE PROPERTIES OF T300/AFR800 COMPOSITE LAMINATES

Composite Material Properties				
Material System - T300/AFR 800 Fiber - T300 Matrix - AFR 800 Maximum Rated Temperature - 350°F (177°C) Resin Content - 30.5% by wt. Fiber Content - 59.8% by vol. Void Content - ≐ 0% by vol.		Prepreg by - Hexcel Laminate Sp. Gr. - 1.57 Nominal Ply Thickness - 0.0057 inch No. of panels from which specimens were tested in this table - 5 Thickness of specimen - 8 ply		Graphite/Epoxy
TENSION: ±45°				
	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{tu} [ksi](MPa)	[26.4] (182)	[23.2] (160)	[16.8] (116)	[16.3] (112)
Stnd.Dev. [ksi](MPa)	[1.00] (6.9)	[1.03] (7.1)	[1.12] (7.7)	[0.86] (5.9)
Range [ksi](MPa)	[25.2-27.8] (174-191)	[21.5-24.1] (148-166)	[15.4-18.0] (106-124)	[15.3-17.1] (105-118)
No. of Specimens	5	5	5	5
F_x^{tpl} [ksi](MPa)	[9.37] (64.6)	[4.69] (32.3)	[4.93] (34.0)	[2.13] (14.7)
Stnd.Dev. [ksi](MPa)	[2.36] (16.3)	[1.14] (7.85)	[0.36] (2.48)	[0.34] (2.34)
No. of Specimens	5	5	5	5
E_x^t [Msi](GPa)	[2.28] (15.7)	[2.35] (16.2)	[2.14] (14.7)	[1.62] (11.2)
Stnd.Dev. [Msi](GPa)	[0.12] (0.83)	[0.16] (1.10)	[0.11] (0.76)	[0.12] (0.83)
No. of Specimens	5	5	5	5
ε_x^{tu} [μin/in](μcm/cm)	>12,080[1]	17,630	>21,530[1]	>39,450[1]
Stnd. Dev.	---	1,630	> 7,090	---
No. of Specimens	5	5	5	5
ν_{xy}^t	0.69	0.75	0.78	0.88
Stnd. Dev.	0.04	0.04	0.01	0.06
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3039			

[1]Some strain gages lost before completion of test.

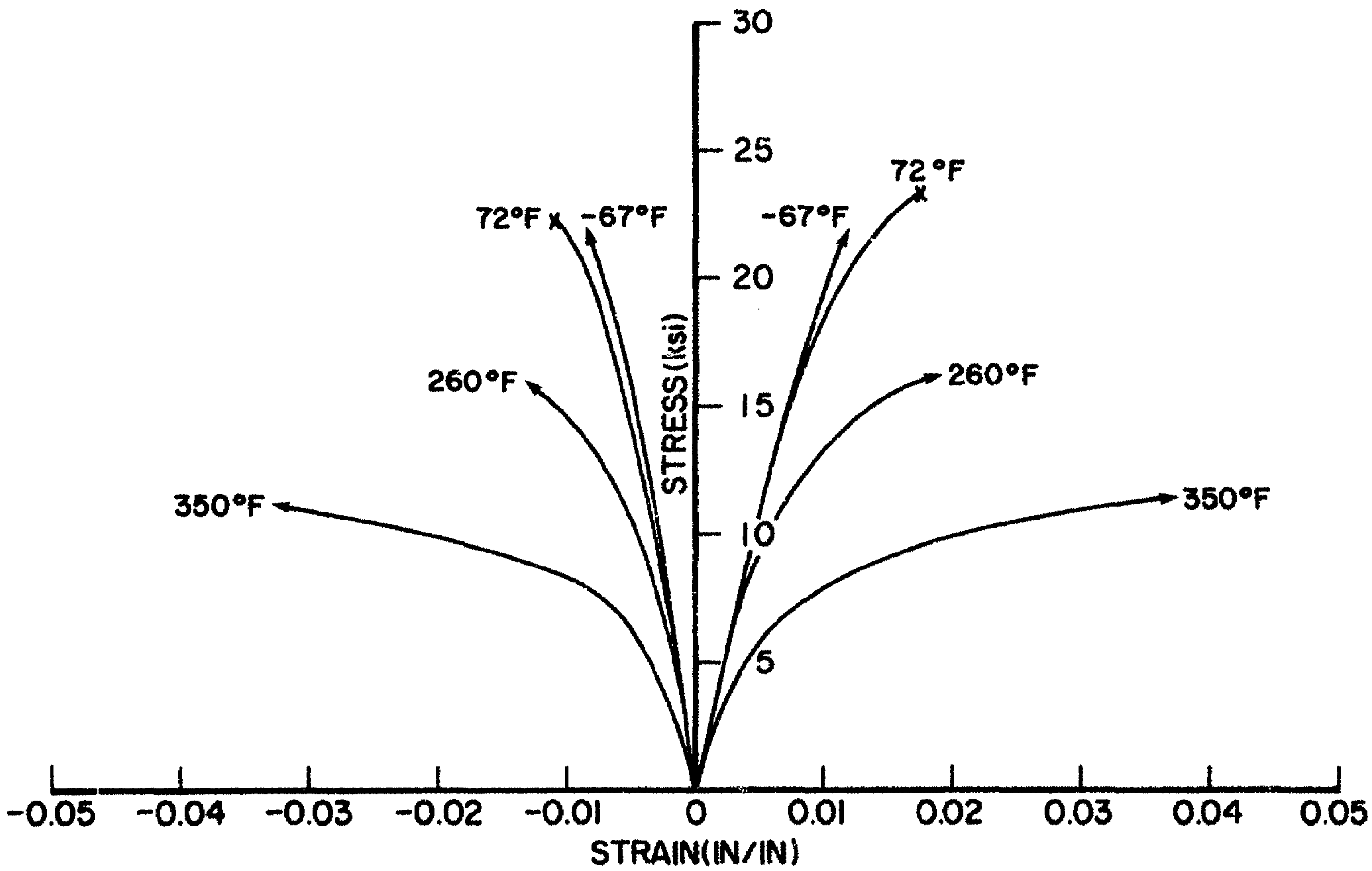


Figure 11. Tensile Stress-Strain Curve for Bidirectional T300/AFR800 Composite Laminates: ±45° Fiber Orientation.

TABLE 11

COMPRESSIVE PROPERTIES OF T300/AFR800 COMPOSITE LAMINATES

Composite Material Properties				
Material System - T300/AFR800 Fiber - T300 Matrix - AFR800 Maximum Rated Temperature - 350°F(177°C) Resin Content - 24.7% by wt. Fiber Content - 71.1% by vol. Void Content - ≐ 0% by vol. Thickness of each type specimen: 0° - 20 ply ; 90° - 20 ply	Prepreg by - Hexcel Laminate Sp. Gr. - 1.61 Nominal Ply Thickness - 0.0050 inch No. of panels from which specimens were tested in this table - 2	Graphite/Epoxy		
COMPRESSION: 0°				
	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{cu} [ksi](MPa)	[205.6] (1417)	[174.6] (1203)	[188.2] (1297)	[164.2] (1131)
Stnd. Dev. [ksi](MPa)	[17.0] (117)	[23.0] (158)	[29.4] (203)	[27.2] (187)
Range [ksi](MPa)	[186.4-224.8] (1284-1549)	[145.6-192.9] (1003-1329)	[149.5-220.5] (1030-1519)	[130.4-206.3] (898-1421)
No. of Specimens	5	5	5	5
F_x^{cpl} [ksi](MPa)	[66.1] (455)	[44.8] (309)	[75.4] (520)	[71.3] (491)
Stnd. Dev. [ksi](MPa)	[15.0] (103)	[38.7] (267)	[33.3] (229)	[53.0] (365)
No. of Specimens	5	5	5	5
E_x^c [Msi](GPa)	[19.15] (132)	[15.98] (110)	[18.38] (127)	[20.71] (143)
Stnd. Dev. [Msi](GPa)	[2.19] (15.1)	[2.85] (19.6)	[3.24] (22.3)	[2.64] (18.2)
No. of Specimens	5	5	5	5
ϵ_x^{cu} [μin/in](μcm/cm)	18,300	14,700	14,400	8,300
Stnd. Dev.	5,600	2,430	2,000	1,400
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3410			
COMPRESSION: 90°				
F_y^{cu} [ksi](MPa)	[44.2] (305)	[39.7] (274)	[28.4] (196)	[27.7] (191)
Stnd. Dev. [ksi](MPa)	[13.8] (95)	[4.8] (33)	[1.5] (10)	[3.9] (27)
Range	[23.9-55.8] (165-384)	[32.4-45.7] (223-315)	[26.7-29.9] (184-206)	[23.0-32.7] (158-225)
No. of Specimens	5	5	5	5
F_y^{cpl} [ksi](MPa)	[13.7] (95)	[32.8] (226)	[18.9] (130)	[22.3] (154)
Stnd. Dev. [ksi](MPa)	[6.8] (47)	[15.7] (108)	[12.4] (85)	[11.0] (76)
No. of Specimens	5	5	5	5
E_y^c [Msi](GPa)	[1.70] (11.7)	[2.50] (17)	[1.50] (10.3)	[2.02] (13.9)
Stnd. Dev. [Msi](GPa)	[0.24] (1.7)	[0.27] (1.9)	[0.09] (0.6)	[0.57] (3.9)
No. of Specimens	5	5	5	5
ϵ_y^{cu} [μin/in](μcm/cm)	31,500	17,900+[1,2]	12,700+[1,2]	25,800
Stnd. Dev.	6,600	9,000	4,400	9,800
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3410			

[1]Ultimate strain values represent maximum observed strain rather than ultimate values.
[2]Two of five specimens exhibited evidence of buckling.

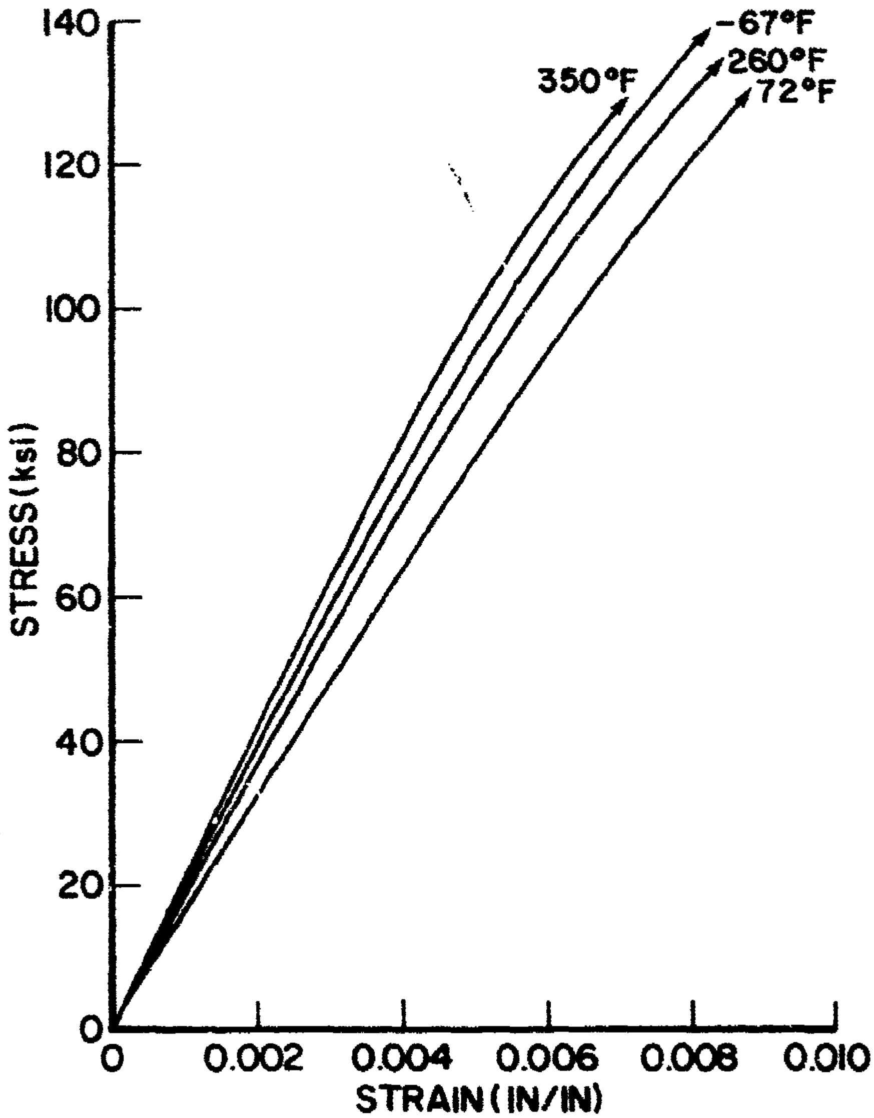


Figure 12. Compressive Stress-Strain Curves for Unidirectional T300/AFR800 Composite Laminates: 0° Fiber Orientation.

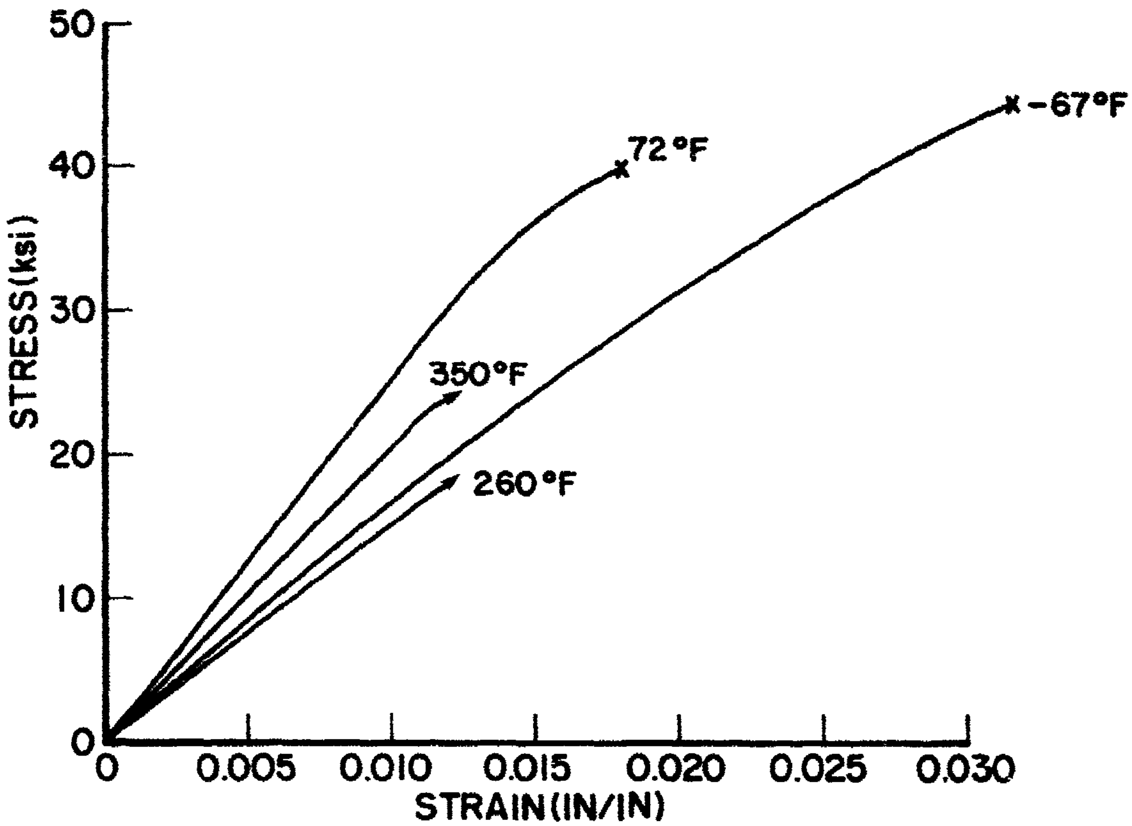


Figure 13. Compressive Stress-Strain Curves for Unidirectional T300/AFR800 Composite Laminates: 90° Fiber Orientation.

TABLE 12

FLEXURAL PROPERTIES OF T300/AFR800 COMPOSITE LAMINATES

Composite Material Properties

Material System - T300/AFR 800	Prepreg by - Hexcel ; Graphite/Epoxy
Fiber - T300 Matrix - AFR 800	Laminate Sp. Gr. - 1.69
Maximum Rated Temperature - 350°F(177°C)	Nominal Ply Thickness - 0.0049 inch
Resin Content - 23.8% by wt.	No. of panels from which specimens were tested in this table - 2
Fiber Content - 75.5% by vol.	
Void Content - ~0% by vol.	
Thickness of each type specimen: 0° - 14 ply ; 90° - 14 ply	

FLEXURE: 0°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{fu} [ksi](MPa)	[291.6](2009)	[280.1](1930)	[218.2](1503)*	[186.8](1287)*
Stnd.Dev. [ksi](MPa)	[8.2] (56)	[4.4] (30)	[10.9] (75)	[5.3] (37)
Range [ksi](MPa)	[278.1-299.7] (1916-2065)	[272.9-284.9] (1880-1963)	[206.5-230.0] (1423-1585)	[181.3-192.5] (1249-1326)
No. of Specimens	5	5	5	5
E_x^f [Msi](GPa)	[20.11](138.5)	[20.70](142.6)	[20.82](143.4)	[19.94](137.4)
Stnd.Dev. [Msi](GPa)	[1.17] (8.06)	[0.74] (5.10)	[0.42] (2.89)	[0.21] (1.45)
No. of Specimens	5	5	5	5
Test Method Reference	4 pt. flexure Design Guide: Jan. 1971 } Corresponds to ASTM D790 except for loading points and loading speed.			

FLEXURE: 90°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_y^{fu} [ksi](MPa)	[14.90](102.7)	[14.10] (97.1)	[10.68] (73.6)	[11.21] (77.2)
Stnd.Dev. [ksi](MPa)	[1.75] (12.1)	[0.36] (2.48)	[0.44] (3.03)	[1.31] (9.03)
Range [ksi](MPa)	[13.02-17.71] (89.7-122.0)	[13.57-14.43] (93.5-99.4)	[10.21-11.21] (70.3-77.2)	[9.68-12.80] (66.7-88.2)
No. of Specimens	5	5	5	5
E_y^f [Msi](GPa)	[1.67] (11.51)	[1.27] (8.75)	[1.17] (10.53)	[1.13] (7.79)
Stnd.Dev. [Msi](GPa)	[0.06] (0.41)	[0.04] (0.28)	[0.07] (0.48)	[0.08] (0.55)
No. of Specimens	4	5	5	5
Test Method Reference	4 pt. flexure Design Guide; Jan. 1971 } Corresponds to ASTM D790 except for loading points and loading speed.			

*At the two higher test temperatures, the 0° specimens failed by delamination rather than fracture at the lower plies.

TABLE 13

SHEAR PROPERTIES OF T300/AFR800
COMPOSITE LAMINATES

Composite Material Properties				
Material System - AFR800/T300 Fiber - T300 Matrix - AFR800 Maximum Rated Temperature - 350°F(177°C) Resin Content - 29.4% by wt. Fiber Content - 65.5% by vol. Void Content - ≈0.4% by vol. Thickness of each type specimen - Inplane - 8 ply ; Interlaminar - 15 ply		Prepreg by - Hexcel Laminate Sp. Gr. - 1.58 Nominal Ply Thickness - 0.0054 inch No. of panels from which specimens were tested in this table - 6		Graphite/Epoxy
INPLANE SHEAR				
	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F^{su}_{xy} [ksi](MPa)	[13.2] (91.0)	[11.5] (79.9)	[8.4] (58.0)	[8.1] (55.8)
Stnd.Dev.[ksi](MPa)	[0.50] (3.45)	[0.52] (3.58)	[0.55] (3.79)	[0.43] (2.95)
Range [ksi](MPa)	[12.6-13.9] (87.0-95.5)	[10.8-12.0] (74.4-82.7)	[7.7-9.0] (53.0-62.0)	[7.7-8.6] (52.5-59.0)
No. of Specimens	5	5	5	5
G^{s}_{xy} [Msi](MPa)	[0.68] (4.66)	[0.68] (4.69)	[0.61] (4.22)	[0.43] (2.94)
Stnd.Dev.[Msi](MPa)	[0.03] (0.18)	[0.05] (0.34)	[0.03] (0.23)	[0.02] (0.14)
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3518			
INTERLAMINAR SHEAR				
F^{isu} [ksi](MPa)	[18.17] (125.2)	[15.27] (105.2)	[11.77] (81.1)	[9.63] (66.4)
Stnd.Dev.[ksi](MPa)	[0.92] (6.34)	[0.79] (5.4)	[0.69] (4.75)	[0.33] (2.27)
Range [ksi](MPa)	[17.27-19.27] (119.0-132.8)	[14.37-17.16] (99.0-118.2)	[11.02-12.81] (75.9-88.3)	[9.27-10.00] (63.9-68.9)
No. of Specimens	5	10	5	5
Test Method Reference	ASTM D2344			

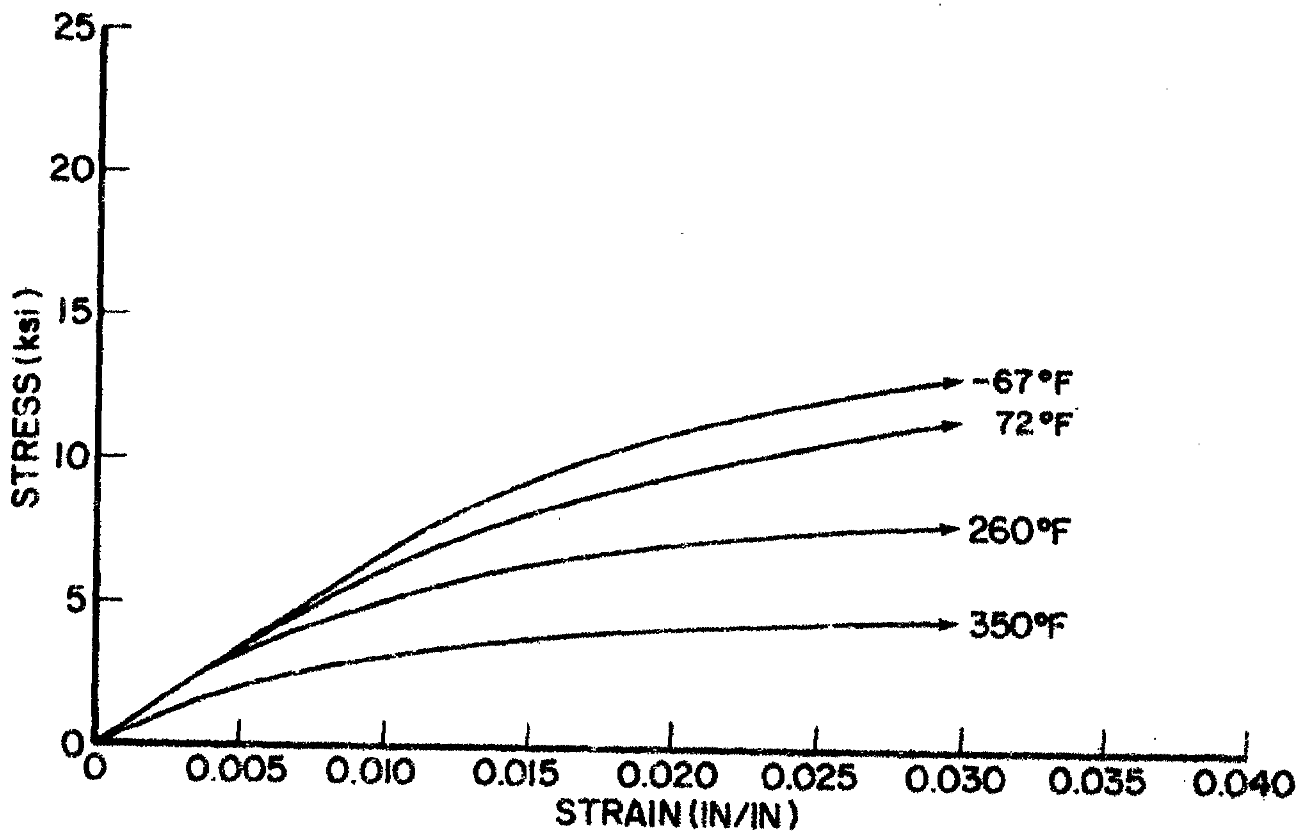


Figure 14. Inplane Shear Stress-Strain Curves for T300/AFR800 Composite Laminates.

TABLE 14

TENSILE, COMPRESSIVE AND SHEAR PROPERTIES OF T300/AFR800 COMPOSITE LAMINATES AFTER HUMIDITY AGING

Composite Material Properties

Material System – T300/AFR800	Prepared by – [illegible]
Fiber – T300 Matrix – AFR800	Laminate Spec. Gr. – 1.[illegible]
Maximum Rated Temperature – [illegible]°F(177°C)	Nominal Ply Thickness – 0.[illegible] inch
Resin Content – [illegible] by wt.	No. of panels from which specimens were tested in this table – [illegible]
Fiber Content – 71.2% by vol.	Aging Conditions – [illegible]°F([illegible]°C) & [illegible] R.H.
Void Content – [illegible] by vol.	Graphite/Epoxy
Thickness of each type specimen: Tension – [illegible] ply; Compr. – [illegible] ply; Shear – [illegible] ply	

TENSION: 90°

	[illegible]	250°F(121°C)	[illegible]	250°F(121°C)
Exposure Time (hrs)	[illegible]	[illegible]	[illegible]	[illegible]
Weight Gain(% of orig. dry wt.)	0.[illegible]	0.[illegible]	1.2[illegible][1]	1.27[1]
Stnd. Dev. (%)	[illegible]	[illegible]	0.[illegible]	[illegible]
No. of Specimens	5	5	5	5
F_y^{tu} [ksi](MPa)	[illegible] ([illegible])	[illegible] ([illegible])	[illegible] ([illegible])	[1.49] ([illegible])
Stnd. Dev. [ksi](MPa)	[illegible] ([illegible])	[illegible] ([illegible])	[illegible] ([illegible])	[0.21] (1.4)
Range [ksi](MPa)	[4.22-6.37] ([illegible]-41.9)	[illegible] ([illegible])	[illegible]-4.05] ([illegible]-27.5)	[1.28-1.78] ([illegible]-12.3)
No. of Specimens	5	5	4	4
F_y^{tpl} [ksi](MPa)	[1.72] (11.9)	[0.48] ([illegible])	[illegible] ([illegible])	[1.26] (8.7)
Stnd. Dev. [ksi](MPa)	[1.06] (7.3)	[illegible] ([illegible])	[0.49] (3.4)	[0.24] (1.7)
No. of Specimens	5	5	4	4
E_y^t [Msi](GPa)	[1.48] (10.2)	[1.55] (10.7)	[1.45] (10.0)	[1.02] (7.0)
Stnd. Dev. [Msi](GPa)	[0.06] (0.41)	[0.11] (0.76)	[0.07] (0.48)	[0.08] (0.55)
No. of Specimens	5	5	4	4
ϵ_y^{tu} [µin/in](µcm/cm)	3030	2115	2546	1502
Stnd. Dev.	[illegible]	[illegible]	521	[illegible]
No. of Specimens	5	5	4	4
ν^t				
Stnd. Dev.				
No. of Specimens				
Test Method Reference	ASTM [illegible]			

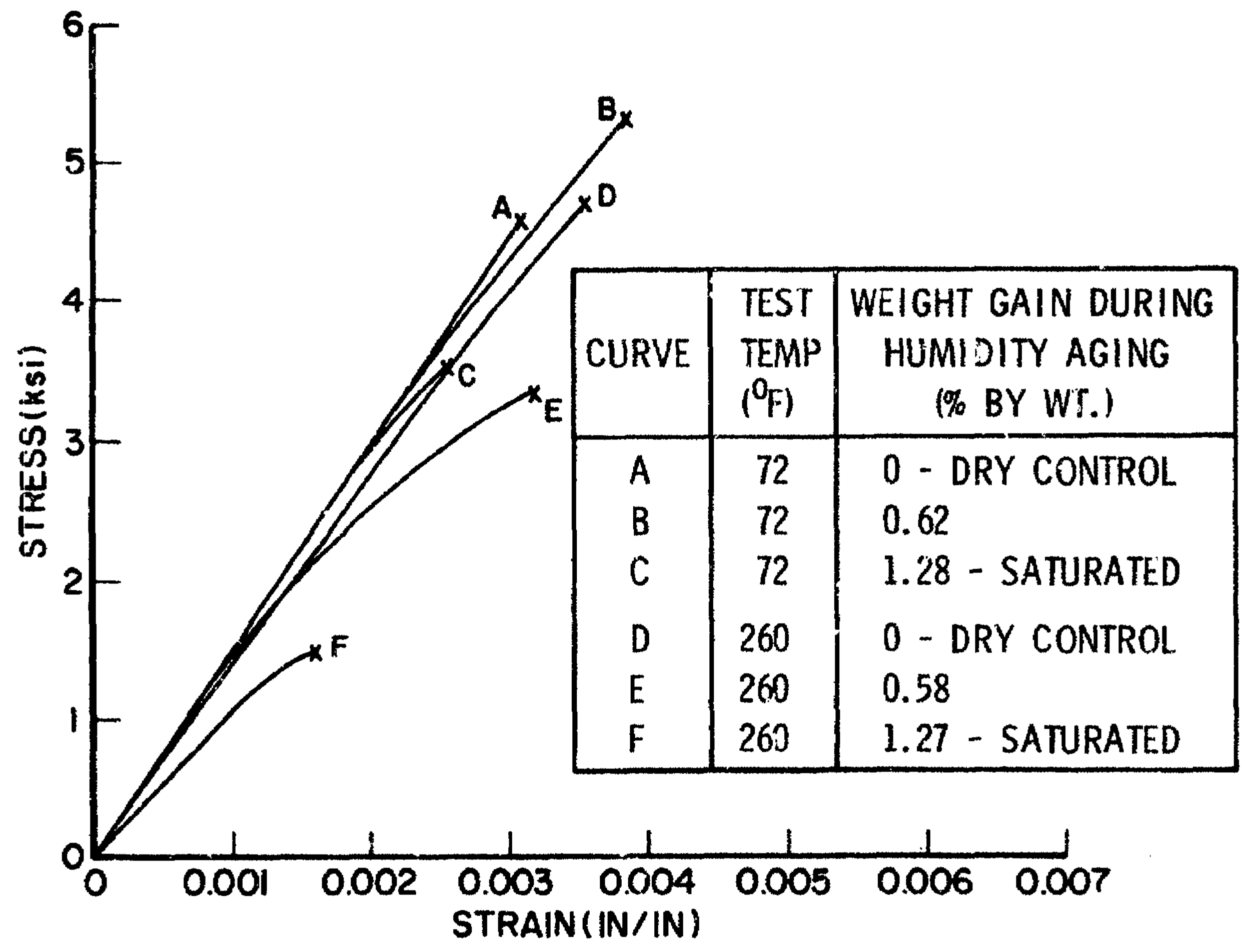
COMPRESSION: 90°

Exposure Time (hrs)	135	164	1904	1904
Weight Gain(% of orig. dry wt.)	0.65	0.81	1.25[1]	1.34[1]
Stnd. Dev. (%)	0.32	0.03	0.10	0.02
No. of Specimens	5	5	4	4
F_y^{cu} [ksi](MPa)	[32.9] (227)	[26.0] (179)	[32.2] (222)	[24.1] (166)
Stnd. Dev. [ksi](MPa)	[3.5] (27)	[1.5] (10)	[2.2] (15)	[1.5] (10)
Range	[31.6-36.6] (218-252)	[24.4-28.1] (168-194)	[29.7-33.8] (206-233)	[22.7-25.9] (156-178)
No. of Specimens	5	5	3	4
F_y^{cpl} [ksi](MPa)	[14.3] (99)	[9.7] (67)	[17.1] (118)	[11.5] (79)
Stnd. Dev. [ksi](MPa)	[10.2] (70)	[2.8] (19)	[13.8] (95)	[2.2] (15)
No. of Specimens	5	5	3	4
E_y^c [Msi](GPa)	[1.78] (12)	[1.84] (13)	[1.88] (13)	[1.63] (11)
Stnd. Dev. [Msi](GPa)	[0.2] (1)	[0.9] (6)	[0.5] (3)	[0.4] (3)
No. of Specimens	5	5	3	4
ϵ_y^{cu} [µin/in](µcm/cm)	41,100	36,300	37,400	33,900
Stnd. Dev.	14,000	13,200	16,700	14,400
No. of Specimens	5	5	3	4
Test Method Reference	ASTM D3410			

INTERLAMINAR SHEAR

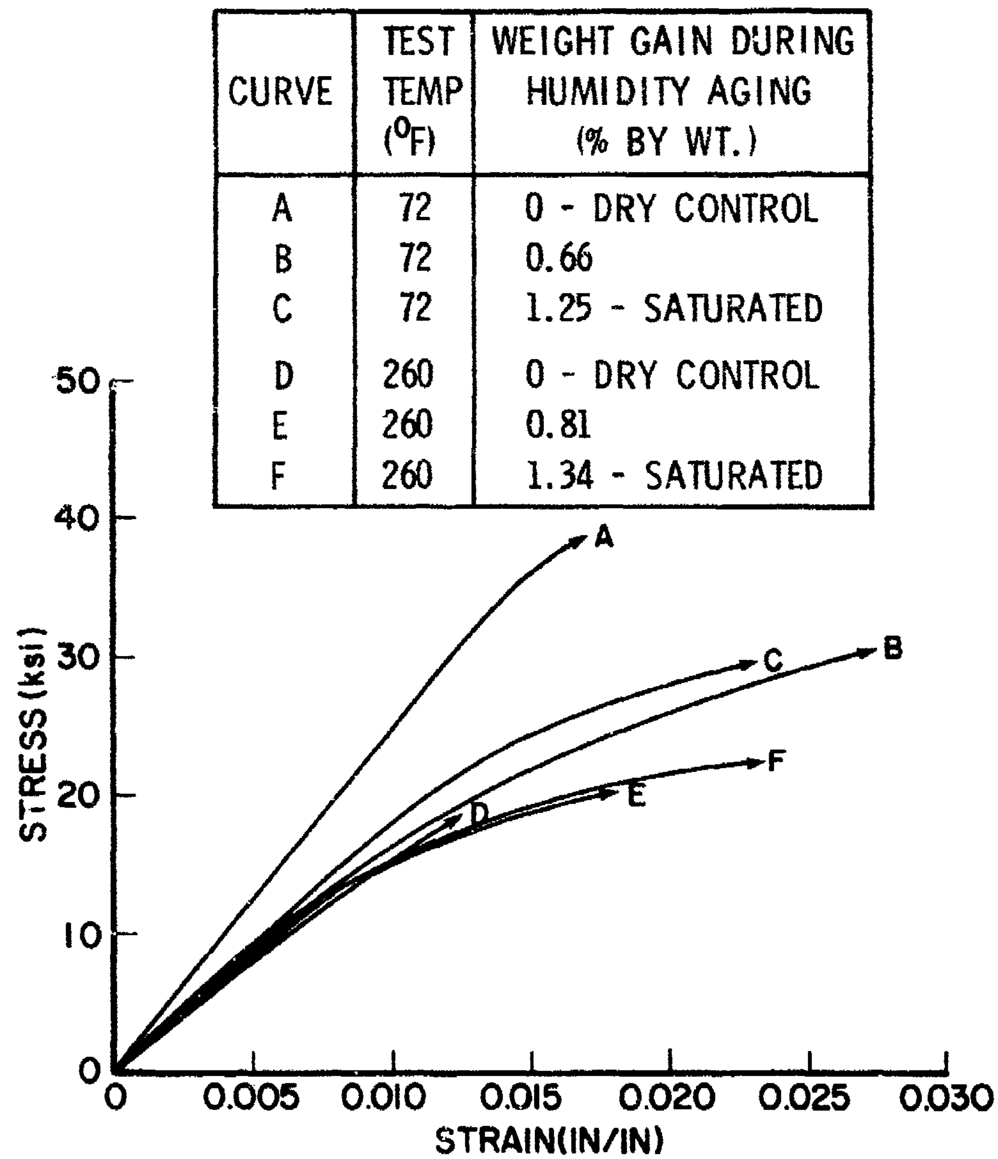
Exposure Time (hrs)	27	27	1206	1203
Weight Gain(% of orig. dry wt.)	0.67	0.78	1.26[1]	1.26[1]
Stnd. Dev. (%)	0.15	0.19	0.17	0.18
No. of Specimens	10	3	10	5
Strength [ksi](MPa)	[15.64] (107.7)	[10.56] (72.8)	[13.76] (94.9)	[7.47] (51.5)
Stnd. Dev. [ksi](MPa)	[0.78] (5.4)	[0.43] (3.0)	[0.64] (4.4)	[0.10] (0.69)
Range [ksi](MPa)	[14.54-16.66] (100.2-114.8)	[10.00-11.19] (69.5-77.1)	[12.85-14.73] (88.5-101.6)	[7.38-7.63] (50.9-52.6)
No. of Specimens	10	3	10	5
Test Method Reference	ASTM D2344			

NOTES: 1. 100% saturation at aging conditions.



CURVE	TEST TEMP (°F)	WEIGHT GAIN DURING HUMIDITY AGING (% BY WT.)
A	72	0 - DRY CONTROL
B	72	0.62
C	72	1.28 - SATURATED
D	260	0 - DRY CONTROL
E	260	0.58
F	260	1.27 - SATURATED

Figure 15. Tensile Stress-Strain Curves for Unidirectional T300/AFR800 Composite Laminates After Humidity Aging at 160°F (71°C) and 100% R.H.: 90° Fiber Orientation.



CURVE	TEST TEMP (^{0}F)	WEIGHT GAIN DURING HUMIDITY AGING (% BY WT.)
A	72	0 - DRY CONTROL
B	72	0.66
C	72	1.25 - SATURATED
D	260	0 - DRY CONTROL
E	260	0.81
F	260	1.34 - SATURATED

Figure 16 . Compressive Stress-Strain Curves for Unidirectional T300/AFR800 Composite Laminates After Humidity Aging at 160°F (71°C) and 100% R.H.: 90° Fiber Orientation.

TABLE 15

CREEP PROPERTIES OF T300/AFR800 COMPOSITE LAMINATES

Composite Material Properties	
Material System - T300/AFR800 Fiber - T300 Matrix - AFR800 Maximum Temperature Rating - 350°F(177°C) Resin Content - 27.5% by wt. Fiber Content - 68.0% by vol. Void Content - ≤ 0% by vol. Test Method - Straight-sided tension Reference - ASTM D2290 & D3039	Prepreg by - Hexcel Graphite/Epoxy Laminate Sp. Gr. - 1.59 Nominal Ply Thickness - 0.0052 inch No. of panels from which specimens were tested in this table - 24 Thickness of each type specimen: 0° - 6 ply 90° - 15 ply ±45° - 8 ply

CREEP				
Temperature	Fiber Orientation	0°	90°	±45°
72°F(22°C)	Stress Level[ksi](MPa)	[163.8] (1129)	[3.21] (22.1)	[16.27] (112)
	Creep Strain, 500 hr(%)	0.0067	---[4]	0.4039
	No. of Specimens	3	3	3
	Residual Strength[ksi](MPa)	[211.5] (1457)	---	[23.45] (162)
	No. of Specimens	2	0	3
	Stress Level[ksi](MPa)	[143.4] (987)	[2.75] (18.9)	[13.94] (96)
	Creep Strain, 500 hr(%)	0.0002	0.0355	0.2693
	No. of Specimens	3	2[2]	3
	Residual Strength[ksi](MPa)	---	[6.18] (42.6)	---
	No. of Specimens	---	2	---
	Stress Level[ksi](MPa)		[2.29] (15.8)	[11.62] (80)
	Creep Strain, 500 hr(%)		0.0342	0.2046
	No. of Specimens		3	3
	Residual Strength[ksi](MPa)		[5.60] (38.6)	[22.97] (158)
	No. of Specimens		3	3
260°F(127°C)	Stress Level[ksi](MPa)	[174.5] (1202)	[2.81] (19.4)	[13.44] (93)
	Creep Strain, 500 hr(%)	0.1300 at 310 hr.[1]	---[1]	---[4]
	No. of Specimens	1[3]	3[1]	3
	Residual Strength[ksi](MPa)	[208.8] (1439)	[6.11] (42.1)	---
	No. of Specimens	1	1	0
	Stress Level[ksi](MPa)	[155.1] (1068)	[2.58] (17.8)	[11.76] (81)
	Creep Strain, 500 hr(%)	0.0715	0.0610	1.1214
	No. of Specimens	2[2]	3	3
	Residual Strength[ksi](MPa)	[199.7] (1376)	[5.08] (35.0)	[23.08] (159)
	No. of Specimens	2	3	3
	Stress Level[ksi](MPa)	[135.7] (935)	[2.34] (16.1)	[10.08] (70)
	Creep Strain, 500 hr(%)	0.0054	0.0608	0.9367
	No. of Specimens	3	3	3
	Residual Strength[ksi](MPa)	[221.1] (1523)	[4.98] (34.3)	[23.57] (163)
	No. of Specimens	3	3	3
350°F(177°C)	Stress Level[ksi](MPa)	[156.2] (1076)	[2.71] (18.7)	[9.76] (67)
	Creep Strain, 500 hr(%)	0.0646	---[4]	---[4,6]
	No. of Specimens	2[5]	3	2
	Residual Strength[ksi](MPa)	[217.1] (1496)	---	---
	No. of Specimens	3	0	0
	Stress Level[ksi](MPa)	[138.8] (956)	[2.17] (15.0)	[8.14] (56)
	Creep Strain, 500 hr(%)	0.0142	0.2779[1]	1.7298 at 7 hr.[1]
	No. of Specimens	4	1[3]	2
	Residual Strength[ksi](MPa)	[216.9] (1494)	[5.01] (34.5)	[19.35] (133)
	No. of Specimens	4	1	3
	Stress Level[ksi](MPa)	[121.5] (837)	[1.63] (11.2)	[6.51] (45)
	Creep Strain, 500 hr(%)	0.0494	0.3629	2.372 at 120 hr.[4]
	No. of Specimens	2[1]	3	2[2]
	Residual Strength[ksi](MPa)	[186.0] (1282)	[3.93] (27.1)	[16.10] (125)
	No. of Specimens	3	3	2

Notes: All values represent arithmetic average.
All residual strengths determined by tensile test at 72°F.

1. Gage malfunctioned before end of test on one specimen.
2. One specimen failed on loading or during test.
3. Two specimens failed on loading or during test.
4. Three specimens failed on loading or during test.
5. Test oven malfunctioned during test on one specimen.
6. Strain exceeded gage limits on all specimens.

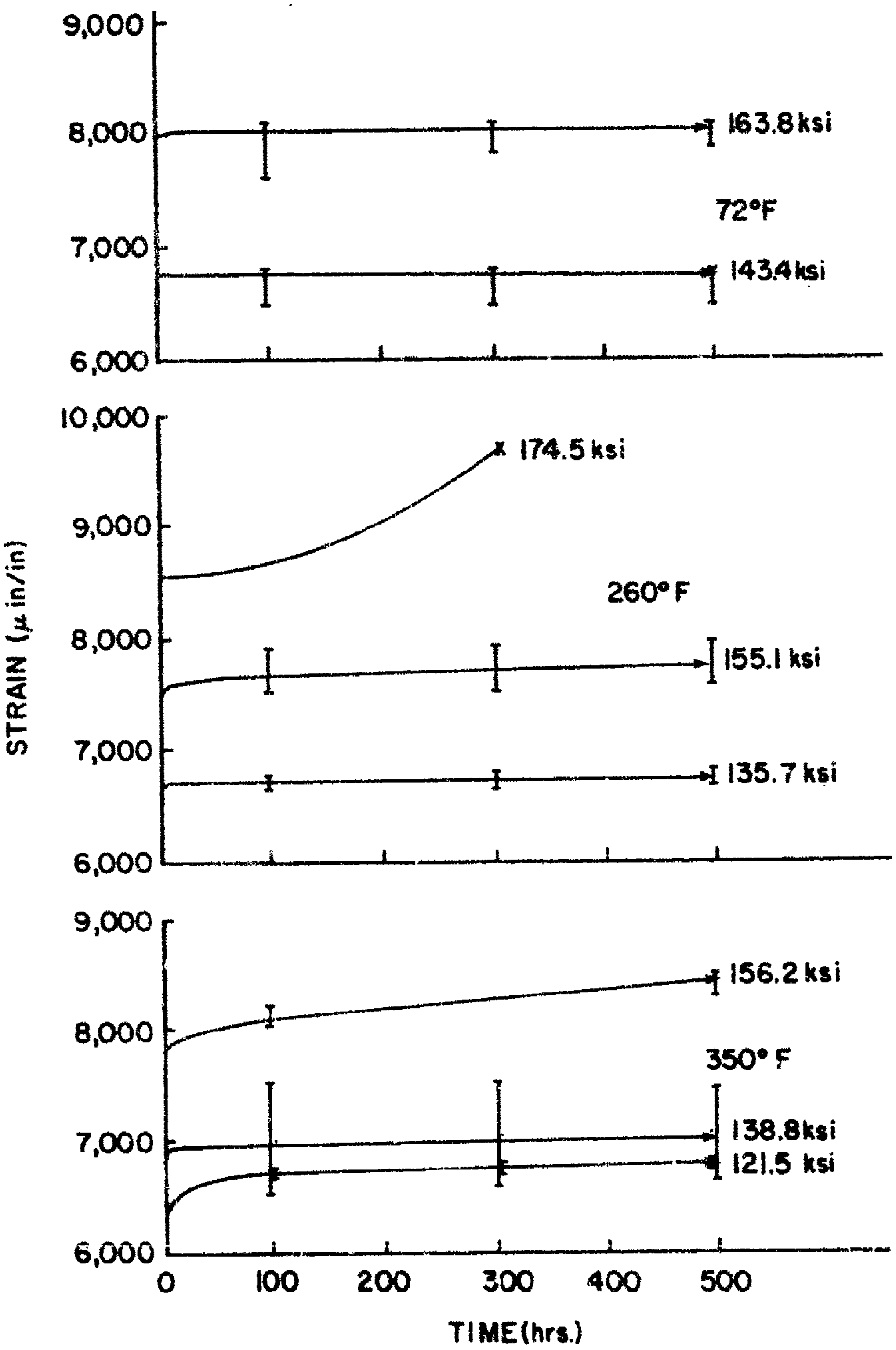


Figure 17. Tensile Creep Behavior of Unidirectional T300/AFR800 Composite Laminates: 0° Fiber Orientation.

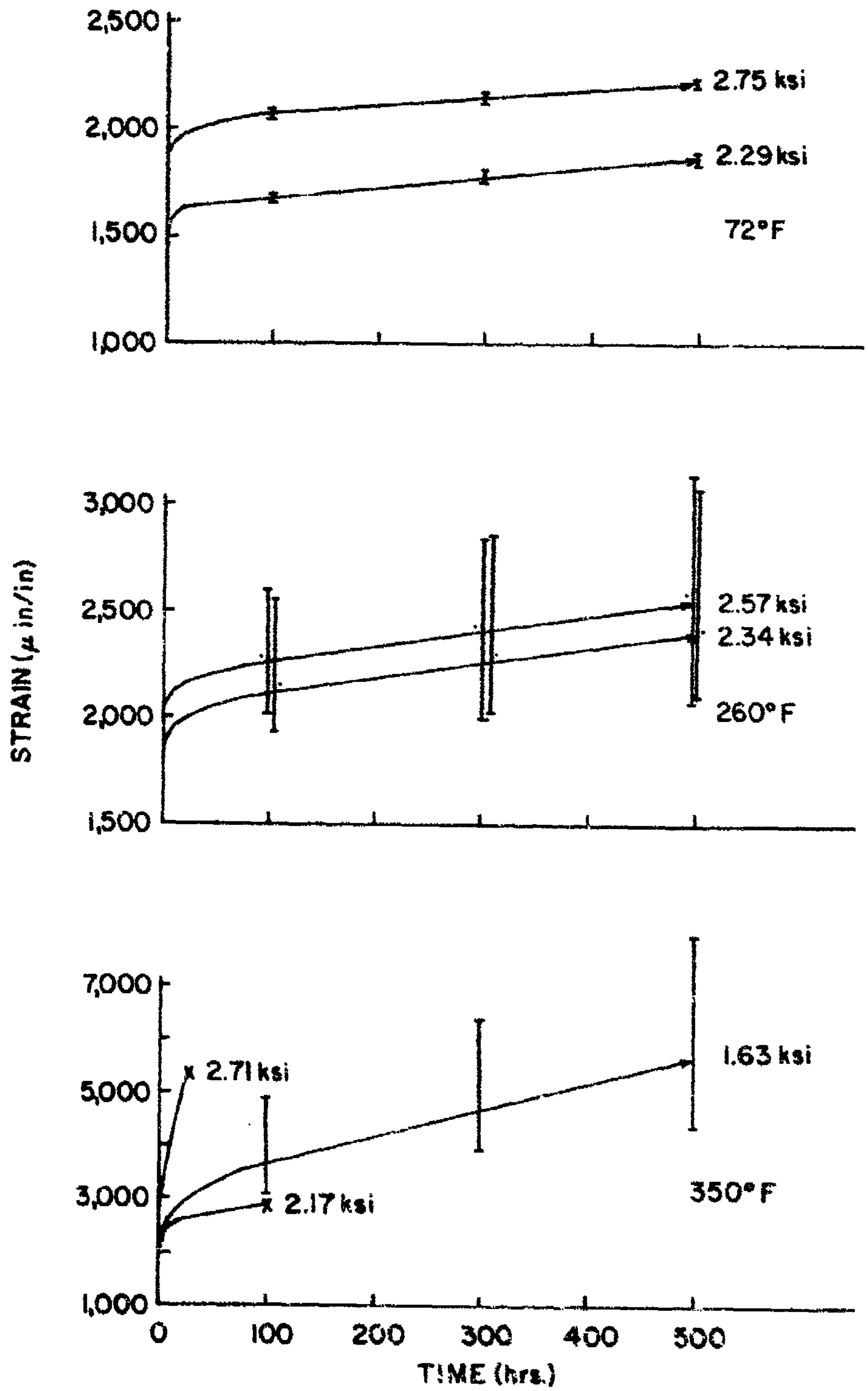


Figure 18. Tensile Creep Behavior of Unidirectional T300/AFR800 Composite Laminates: 90° Fiber Orientation.

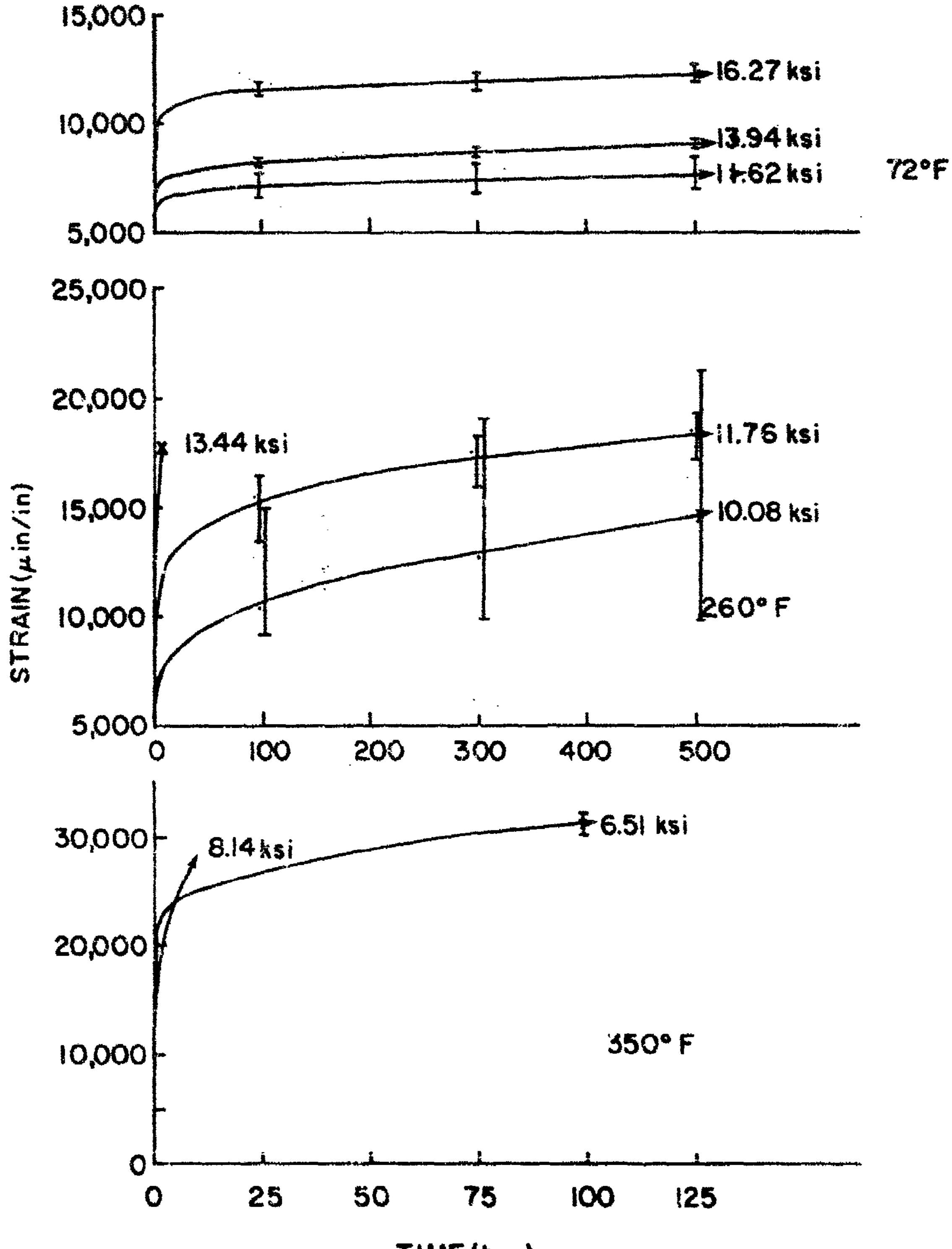


Figure 19. Tensile Creep Behavior of Bidirectional T300/AFR800 Composite Laminates: ±45° Fiber Orientation.

TABLE 16

STRESS RUPTURE PROPERTIES OF T300/AFR800 COMPOSITE LAMINATES

Composite Material Properties

Material System - T300/AFR800	Prepreg by - Hexcel	Graphite/Epoxy
Fiber - T300 Matrix-AFR800	Laminate Sp. Gr. - 1.59	
Maximum Temperature Rating - 350°F	Nominal Ply Thickness - 0.0052 inch	
Resin Content - 27.5% by wt.	No. of panels from which specimens were tested in this table - 24	
Fiber Content - 68.0% by vol.	Thickness of each type specimen:	
Void Content - ≈0% by vol.		
Test Method - Straight-sided tension Reference - ASTM D2290 & D3039	0° - 6 ply 90° - 15 ply ±45° - 8 ply	

STRESS RUPTURE

Temperature	Fiber Orientation	0°	90°	±45°
72°F(22°C)	Stress Level[ksi](MPa)	[163.8] (1129)	[2.75] (18.9)	[16.27] (112)
	Time to Failure(hrs)	500[1]	333[2]	500[1]
	No. of Specimens	3	3	3
	Residual Strength[ksi](MPa)	[211.5] (1457)	[6.18] (42.6)	[23.45] (162)
	No. of Specimens	2	2	3
	Stress Level[ksi](MPa)	[143.4] (987)	[2.29] (15.8)	[13.94] (96)
	Time to Failure(hrs)	500[1]	500[1]	500[1]
	No. of Specimens	3	3	3
	Residual Strength[ksi](MPa)	---	[5.60] (38.6)	---
	No. of Specimens	---	2	---
260°F(127°C)	Stress Level[ksi](MPa)	[174.5] (1202)	[2.81] (19.4)	[13.44] (93)
	Time to Failure(hrs)	167[3]	167[3]	0.2[4]
	No. of Specimens	3	3	3
	Residual Strength[ksi](MPa)	[208.8] (1439)	[6.11] (42.1)	---
	No. of Specimens	1	1	---
	Stress Level[ksi](MPa)	[155.1] (1068)	[2.58] (17.8)	[11.76] (81)
	Time to Failure(hrs)	336[2]	500[1]	500[1]
	No. of Specimens	3	3	3
	Residual Strength[ksi](MPa)	[199.7] (1376)	[5.08] (35.0)	[23.08] (159)
	No. of Specimens	2	3	3
350°F(177°C)	Stress Level[ksi](MPa)	[156.2] (1076)	[2.71] (18.7)	[9.76] (67)
	Time to Failure(hrs)	500[1]	23[4]	156[4]
	No. of Specimens	3	3	3
	Residual Strength[ksi](MPa)	[217.1] (1496)	---	---
	No. of Specimens	3	0	0
	Stress Level[ksi](MPa)	[138.8] (956)	[2.17] (15.0)	[8.14] (56)
	Time to Failure(hrs)	500[1]	235[3]	500[1]
	No. of Specimens	4	3	3
	Residual Strength[ksi](MPa)	[216.9] (1494)	[5.01] (34.5)	[19.35] (133)
	No. of Specimens	4	1	3

Notes: All values represent arithmetic averages. All residual strengths determined by tensile test at 72°F (22°C).

1. No failures within 500 hours.
2. Average of one failure and two 500-hour survivals.
3. Average of two failures and one 500-hour survival.
4. Average of three failures.

TABLE 17

FATIGUE PROPERTIES OF T300/AFR800 COMPOSITE LAMINATES

Composite Material Properties

Material System - T300/AFR800
Fiber - T300 Matrix - AFR800
Maximum Temperature Rating - 350°F (177°C)
Resin Content - 26.9% by wt.
Fiber Content - 68.6% by vol.
Void Content - ≐ 0% by vol.
Test Method - Straight-sided tension
Reference - ASTM D3479

Prepreg by - Hexcel
Graphite/Epoxy
Laminate Sp. Gr. - 1.59
Nominal Ply Thickness - 0.0052 inch
No. of panels from which specimens were tested in this table - 25
Thickness of each type specimen:
0° - 6 ply
90° - 15 ply
±45° - 8 ply

TENSILE FATIGUE, R=0.1

Temperature	Fiber Orientation	0°	90°	±45°
72°F (22°C)	Max. Stress [ksi] (MPa)	[143.7] (990)	[3.21] (22.1)	[16.27] (112)
	Lifetime (cycles)	45,336	52,038	17,688
	No. of Specimens	5	6	5
	Residual Strength [ksi] (MPa)	---	---	---
	No. of Specimens	0	0	0
	Max. Stress [ksi] (MPa)	[134.7] (928)	[2.98] (20.5)	[15.11] (104)
	Lifetime (cycles)	3,960,636	29,091	47,600
	No. of Specimens	6	5	5
	Residual Strength [ksi] (MPa)	[211.0] (1454)	---	---
	No. of Specimens	4	0	0
	Max. Stress [ksi] (MPa)	[125.7] (866)	[2.75] (18.9)	[13.94] (96)
	Lifetime (cycles)	2,124,065	1,164,422	1,403,780
	No. of Specimens	6	5	5
	Residual Strength [ksi] (MPa)	[203.3] (1401)	[5.49] (37.8)	---
	No. of Specimens	3	2	0
260°F (127°C)	Max. Stress [ksi] (MPa)	[174.5] (1202)	[2.98] (20.5)	[12.60] (87)
	Lifetime (cycles)	8,052	8723	84,080
	No. of Specimens	5	3	5
	Residual Strength [ksi] (MPa)	---	---	---
	No. of Specimens	0	0	0
	Max. Stress [ksi] (MPa)	[155.1] (1069)	[2.81] (19.4)	[11.76] (81)
	Lifetime (cycles)	136,078	51,608	68,513
	No. of Specimens	5	5	5
	Residual Strength [ksi] (MPa)	---	[7.28] (50.2)	---
	No. of Specimens	0	1	0
	Max. Stress [ksi] (MPa)	[145.4] (1002)	[2.57] (17.7)	[10.92] (75)
	Lifetime (cycles)	1,759,820	10^7+	3,449,829
	No. of Specimens	4	1	5
	Residual Strength [ksi] (MPa)	[187.6] (1292)	[6.10] (42.0)	[21.20] (146)
	No. of Specimens	1	1	1

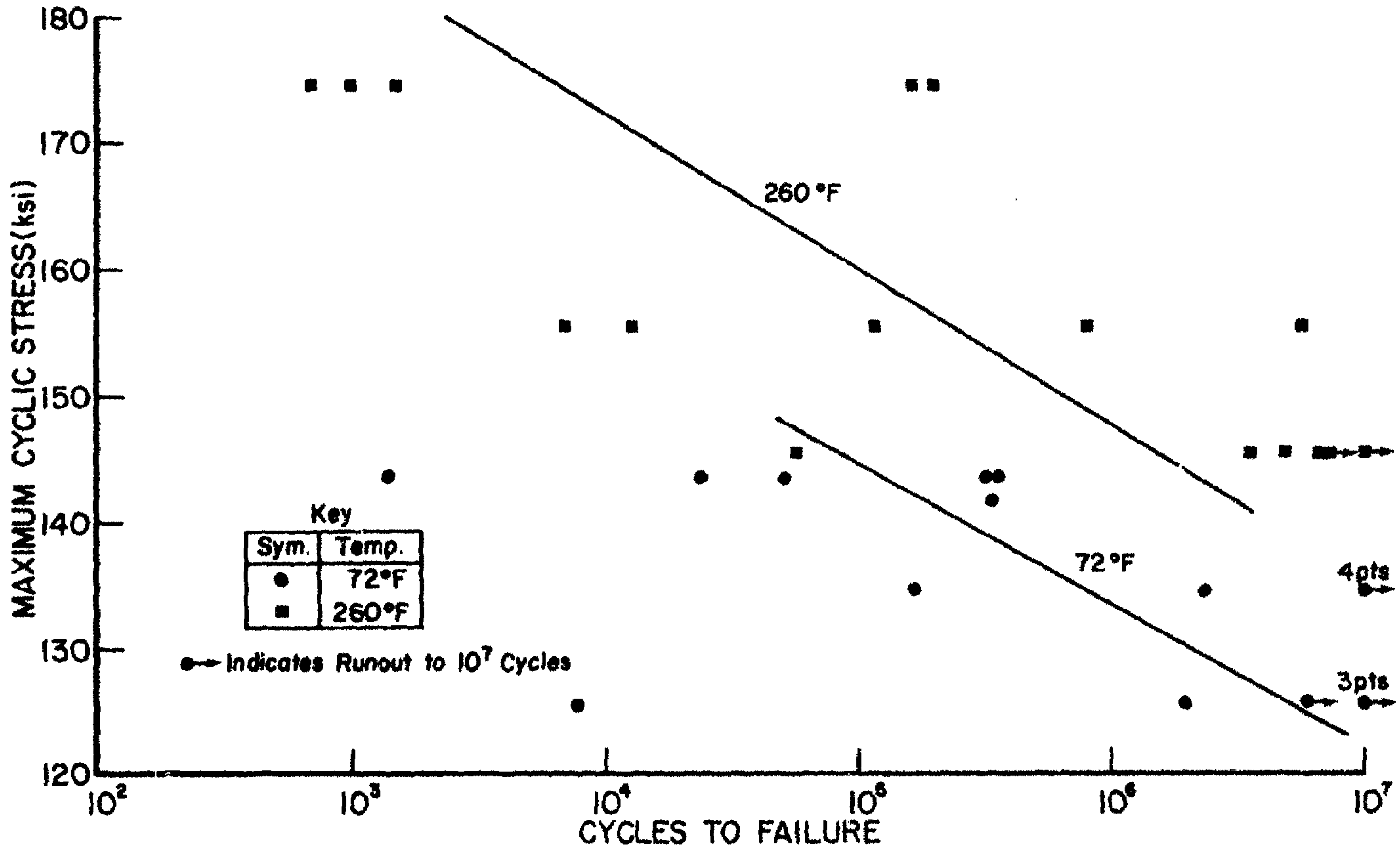


Figure 20. Tensile-Tensile Fatigue Behavior of Unidirectional T300/AFR800 Composite Laminates: 0° Fiber Orientation, R = 0.10, 10 Hz.

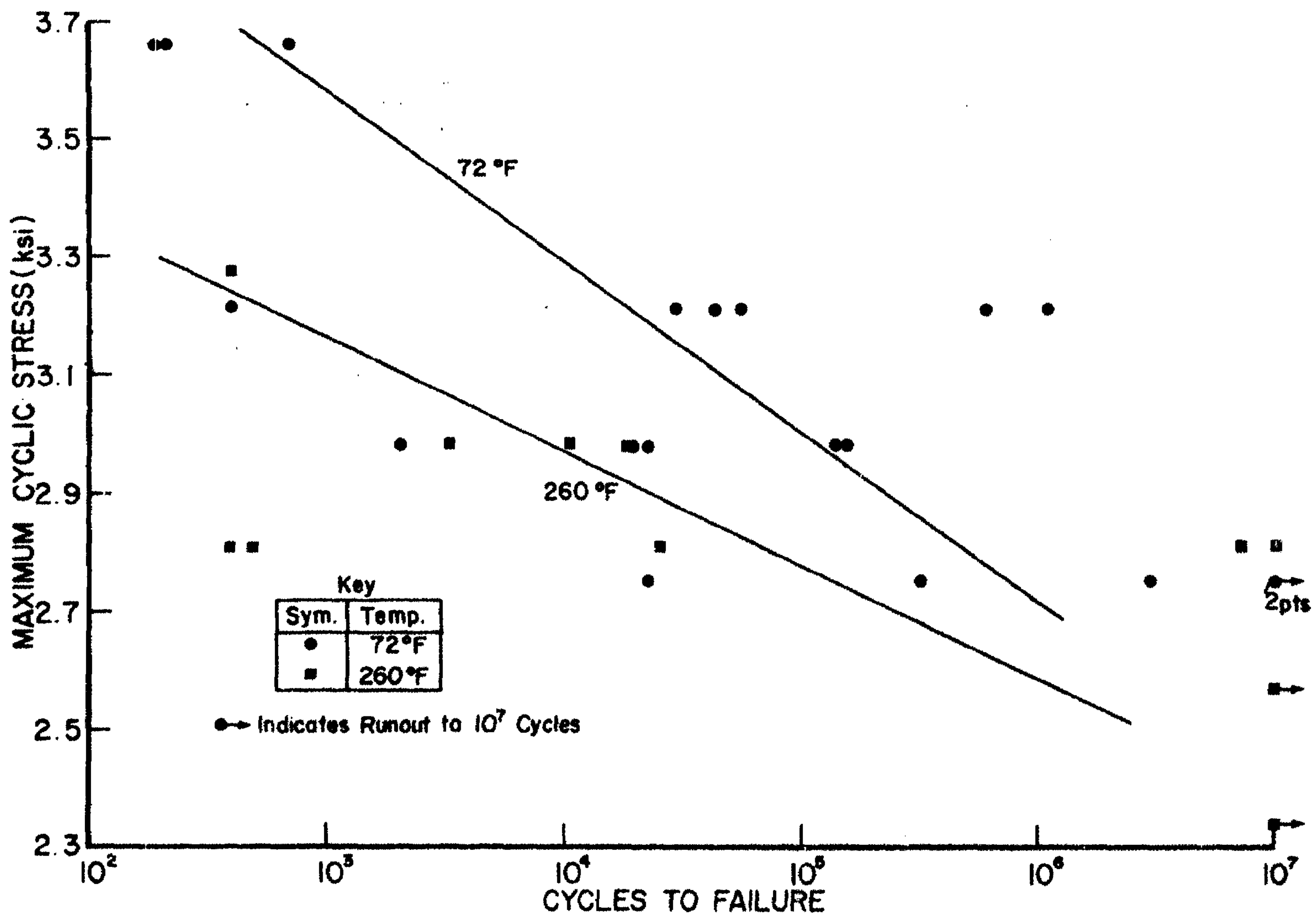


Figure 21. Tensile-Tensile Fatigue Behavior of Unidirectional T300/AFR800 Composite Laminates: 90° Fiber Orientation, R = 0.10, 10 Hz.

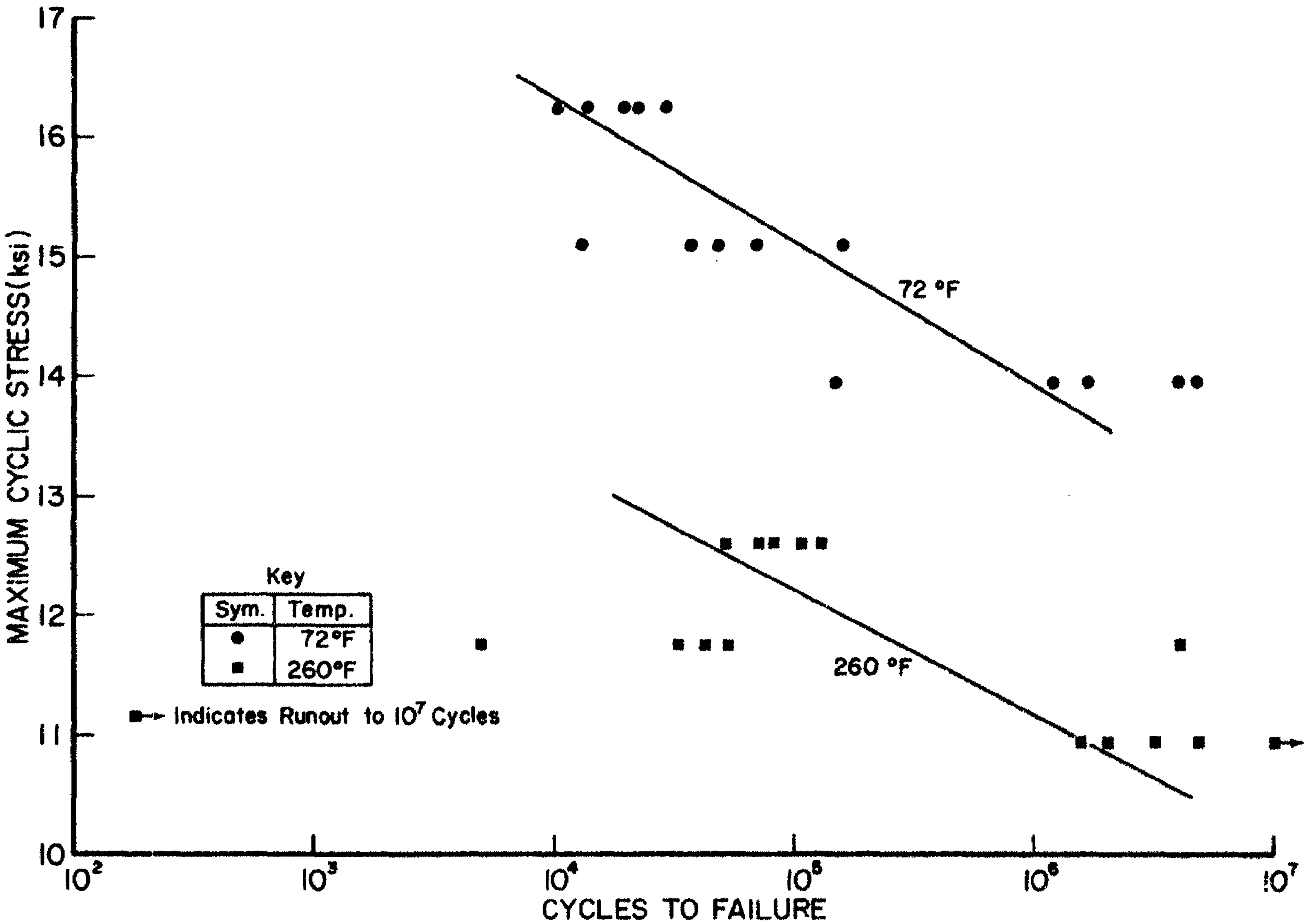


Figure 22. Tensile-Tensile Fatigue Behavior of Bidirectional T300/AFR800 Composite Laminates: ±45° Fiber Orientation, R = 0.10, 10 Hz.

TABLE 18

THERMOPHYSICAL PROPERTIES OF T300/AFR800 COMPOSITE LAMINATES

Composite Material Properties					
Material System - T300/AFR 800 Fiber - T300 Matrix - AFR 800 Maximum Temperature Rating - 350°F(177°C) Resin Content - 26.7% by wt. Fiber Content - 66.5% by vol. Void Content - ≐ 0% by vol. Thickness of each type specimen: Therm. Exp. - 50 ply; Therm. Cond. - 50 ply			Prepreg by - Hexcel Laminate Sp. Gr. -1.59 Average Ply Thickness - 0.0052 inch No. of panels from which specimens were tested in this table - 2 Spec. Ht. - 1 ply Glass Trans. - 14 ply		Graphite/Epoxy
THERMOPHYSICAL PROPERTIES: 0°					
	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)	Test Method
Thermal Expansion[1]					TMA[2]
α_x [μin/in-°F](μcm/cm-°C)	-0.08	-0.37	-0.14	-0.20	
α_y [μin/in-°F](μcm/cm-°C)	12.9	13.6	14.5	16.9	
No. of Specimens per direction	3	3	3	3	
Specific Heat					DSC[3]
C_p [btu/lb.-°F](J/kg-°C)	[0.081](339)	[0.203](849)	[0.302](1263)	[0.308](1288)	
No. of Specimens	3	3	3	3	
Thermal Conductivity[1] k_z [btu-ft/ft^2-hr-°F] (W/m-°C)	[0.371] (0.642)	[0.433] (0.749)	[0.517] (0.894)	[0.555] (0.960)	Comparative
No. of Specimens	3	3	3	3	
Glass Transition Temp.					
Dry [°F](°C)	[468](242)				DMA[4]
Wet [°F](°C)	[381](194)				DMA
THERMOPHYSICAL PROPERTIES: ±45°					
Thermal Expansion[1]					TMA[2]
α_x [μin/in-°F](μcm/cm-°C)	2.6	2.4	2.8	3.2	
No. of Specimens per direction	3	3	3	3	
Thermal Conductivity[1] k_z [btu-ft/ft^2-hr-°F] (W/m-°C)	[0.311] (0.538)	[0.351] (0.607)	[0.406] (0.702)	[0.433] (0.749)	Comparative
No. of Specimens	3	3	3	3	

NOTES: 1. On the unidirectionally reinforced specimens, the x-direction is along the fiber axis, the y-direction is across the fiber axis, and the z-direction is through the thickness (identical to the y-direction). On ±45° bidirectionally reinforced specimens, the x and y directions are identical and oriented at 45° to either fiber direction, while the z-direction is through the thickness.

2. Thermo-Mechanical Analysis.

3. Differential Scanning Calorimetry.

4. Dynamic Mechanical Analysis.

4.2 SiC/5506

This system consisted of 5.6 mil (0.14 mm) silicon carbide fiber (on a carbon core) in an epoxy matrix resin. Both the fiber and resin were AVCO products (Specialty Materials Division, Lowell, Massachusetts). The resin is a 350°F (177°C) curing system which is modified for extra toughness.

Tables 19 through 32 present the data generated for this silicon carbide-epoxy system. Figures 23 through 40 illustrate the stress-strain, fatigue, and creep behavior of this material, as well as the effects of humidity aging upon selected composite properties.

Perhaps the most obvious feature of this system is the substantial decrease in property levels, particularly the resin dominated properties, at the 350°F (177°C) test temperature relative to the 260°F (127°C) test temperature.

The high 0° compressive properties exhibited by this system relative to the other systems tested reflect the beneficial effect of the much larger filament diameter compared to graphite in resisting buckling.

TABLE 19

PROCESSING CONDITIONS FOR SiC/5506 COMPOSITE LAMINATES

Composite Processing Information

Material System - SiC/5506 — SiC/Epoxy

Fiber - 5.6mil SiC **Matrix** - AVCO 5506

Maximum Rated Temperature - 350°F — **Prepreg by** - AVCO

Laminate Processing Schedule

Layup Procedure: The prepreg was stored in a closed wrapper at 0°F (-18°C). Prepreg was warmed to room temperature before removal from wrapper to prevent moisture condensation on pregreg. Plies were cut to desired size with razor knife and stacked in desired sequence (release paper removed from each ply). The stack was placed in the autoclave according to the layup system illustrated in Figure 23. The corprene edge dam serves to restrict fiber flow.

Cure Schedule: Apply full vacuum and hold it throughout the cure cycle. Pressurize to 85 psi above bladder and heat at 4-6°F/min to 350°F. Hold at 350°F for 1 1/2 hours. Cool under pressure and vent vacuum.

Postcure Schedule: After trimming of flash, panels were placed, unrestrained in a circulating air oven and heated to 375°F at 4-6°F/min. They were held at 375°F for four hours then cooled to room temperature.

NOTE: This cure schedule represents one which differs from that originally recommended by AVCO. Due to the slower response of the large autoclave used to fabricate our panels, the cure schedule had to be modified. The original schedule recommended by AVCO was as follows:

> Apply full vacuum. Pressurize to 50 psi above bladder and heat at 4-6°F/min to 350°F, venting vacuum when temperature reaches 135°F. Hold at 350°F for 1-1/2 hours and cool under pressure.

This cure schedule, when followed in our autoclave, produced laminates having a specific gravity of 2.19 and void content of 5.7%.

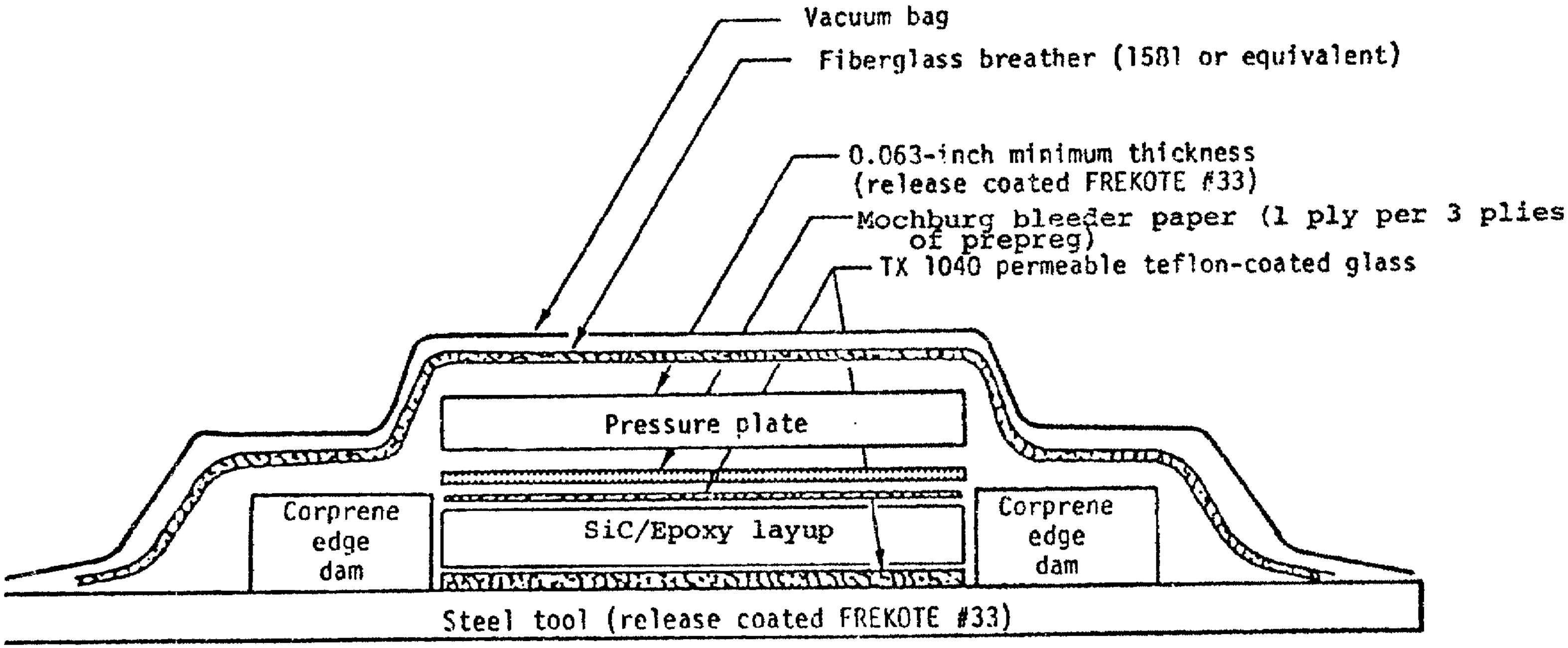


Figure 23. Layup System for SiC/5506 Laminates.

TABLE 20

PREPREG AND COMPOSITE PHYSICAL PROPERTIES

Composite Physical Property Information				
Material System - SiC/5506			SiC/Epoxy	
Fiber - 5.6 mil SiC	Matrix - AVCO 5506			
Maximum Rated Temperature - 350°F (177°C)			Prepreg by - AVCO	
Prepreg Physical Properties				
(Property)	(Stnd.Dev.)	(Range)	(Test Method)	(Ref.)
Volatile Content- 1.40%	0.08%	1.34-1.52%	Advanced	Para. 4.2.3.3
Resin Content- 27.9%	0.6%	27.4-28.6%	Composite	4.2.3.2.1
Resin Flow-			Design Guide	
No. of Rolls Involved- 4				
No. of Batches Involved- 1				
Laminate Physical Properties[1]				
	(Stnd.Dev.)	(Range)	(Test Method)	(Ref.)
No. of Panels- 31				
Fiber Content- 58.6% by vol.	1.3%	53.9-61.2%	Acid Digestion	
Resin Content- 19.0% by wt.	0.9%	17.4-22.0%	AFML-TR-67-243	
Void Content- 0.7% by vol.	0.7%	0.0-2.2%	D2734	ASTM
Laminate Sp. Gr.- 2.36	0.02	2.30-2.41	D792	ASTM
Fiber Sp. Gr.- 3.08[2]	As reported by manufacturer.			
Matrix Sp. Gr.-1.23	As reported by manufacturer.			
Thickness per ply-0.0064 in.	0.0002 in.	0.0061-0.0069 in.	---	---

[1]The properties reported here represent averages for all panels of this material used throughout the program.

[2]Pregreg also contains a glass scrim cloth (4.5% by wt.) with a fiber specific gravity of 2.40.

HPLC ANALYSIS

SAMPLE (CONC.)	AVCO 5506	SAMPLE SIZE	45 mg/ml
MOBILE PHASE 1	ACETONITRILE	MOBILE PHASE 2	WATER
FLOW RATE	2.0 ml/min	PROGRAM	METH. 0
COLUMN(S)	ODS	DETECTOR	TRACOR 970
ATTENUATION	32	WAVE LENGTH	230 nm
CHART SPEED	0.5 cm/min	FULL SCALE (mV)	20mV
DATE	NOVEMBER 28 79	OPERATOR	WOLFE

TIME	WATER	ACETO.
0	76%	24%
20 MIN	18%	82%
21 MIN	1%	99%

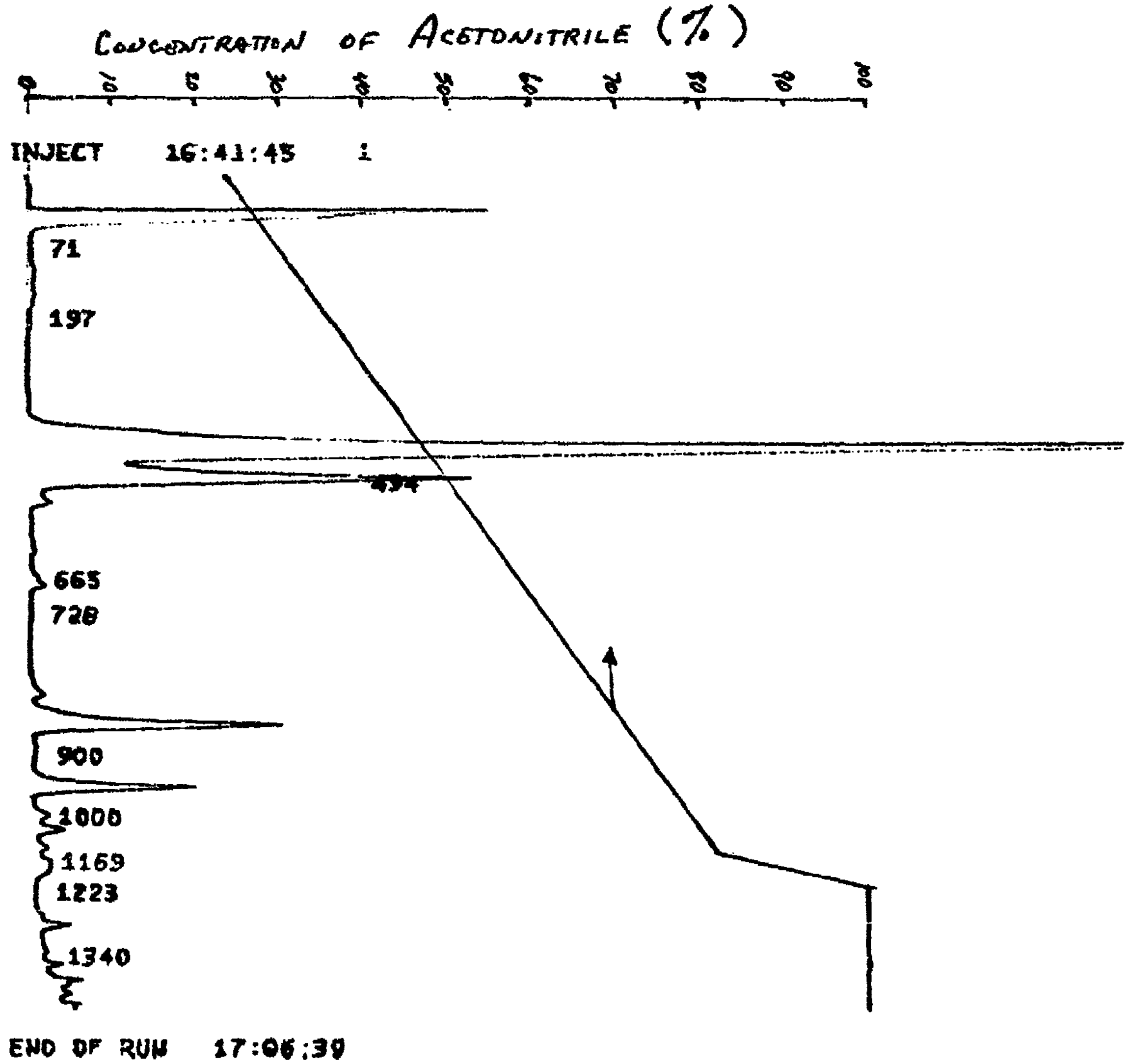


Figure 24. HPLC Analysis of AVCO 5506 Epoxy Resin.

HPLC ANALYSIS

SAMPLE (CONC.) Benzaldehyde SAMPLE SIZE 0.2 mg/ml
MOBILE PHASE 1 Acetonitrile MOBILE PHASE 2 Water
FLOW RATE 2.0 ml/min PROGRAM method O
COLUMN(S) ODS DETECTOR Tracor 970
ATTENUATION 32 WAVE LENGTH 230 nm
CHART SPEED 0.5 cm/min FULL SCALE (mV) 20 mV
DATE NOVEMBER 28 79 OPERATOR WOLFE

TIME	WATER	ACETO.
0	76%	24%
20 MIN	18%	82%
21 MIN	1%	99%

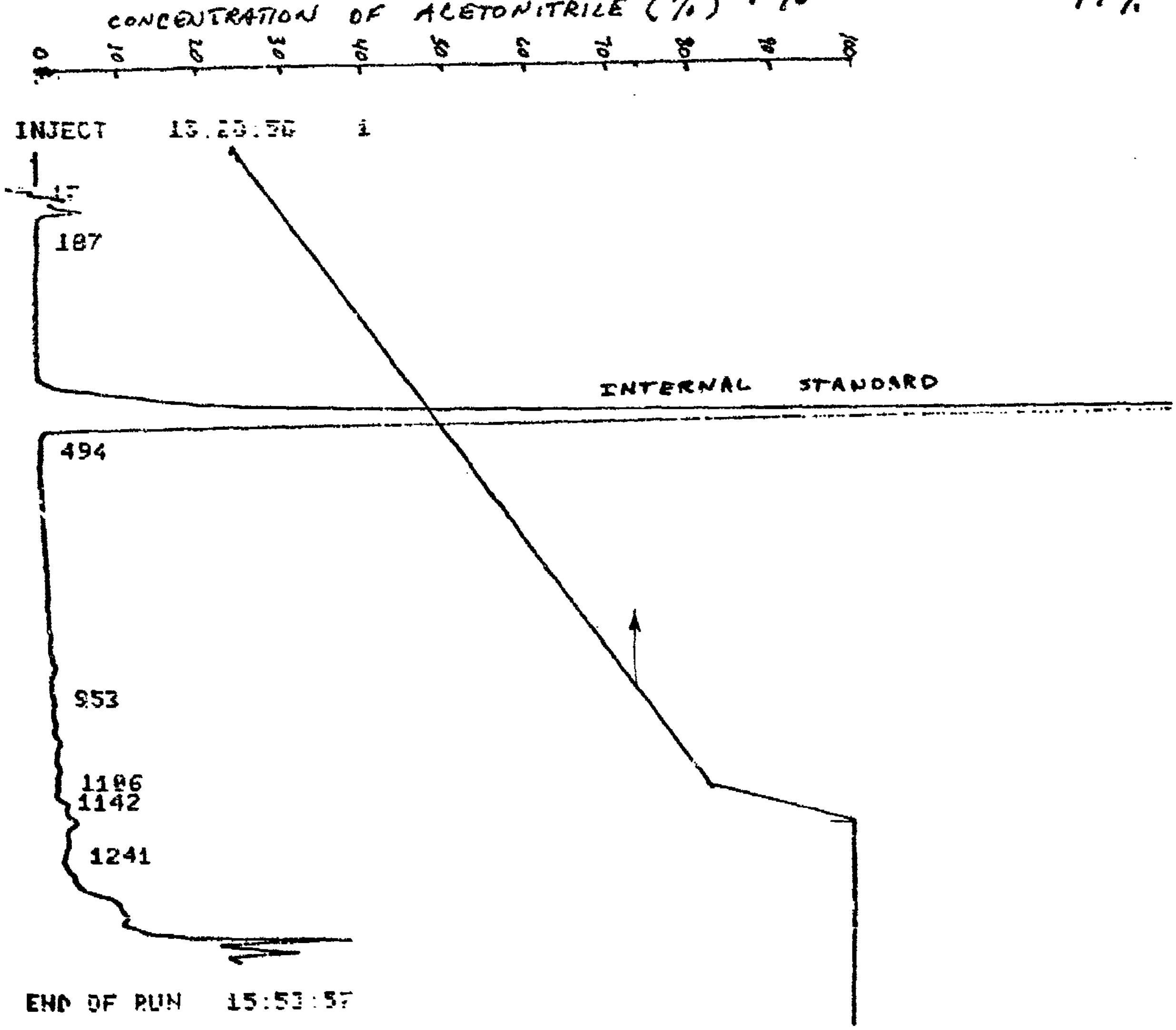


Figure 25. HPLC Analysis of Benzaldehyde.

HPLC ANALYSIS

SAMPLE (CONC.)	EPON 828	SAMPLE SIZE	1.5 mg/ml
MOBILE PHASE 1	Acetonitrile	MOBILE PHASE 2	Water
FLOW RATE	2.0 ml/min	PROGRAM	METH 0
COLUMN(S)	ODS	DETECTOR	Tracor 970
ATTENUATION	32	WAVE LENGTH	230 nm
CHART SPEED	0.5 cm/min	FULL SCALE (mV)	20mV
DATE	DEC 3 79	OPERATOR	WOLFE

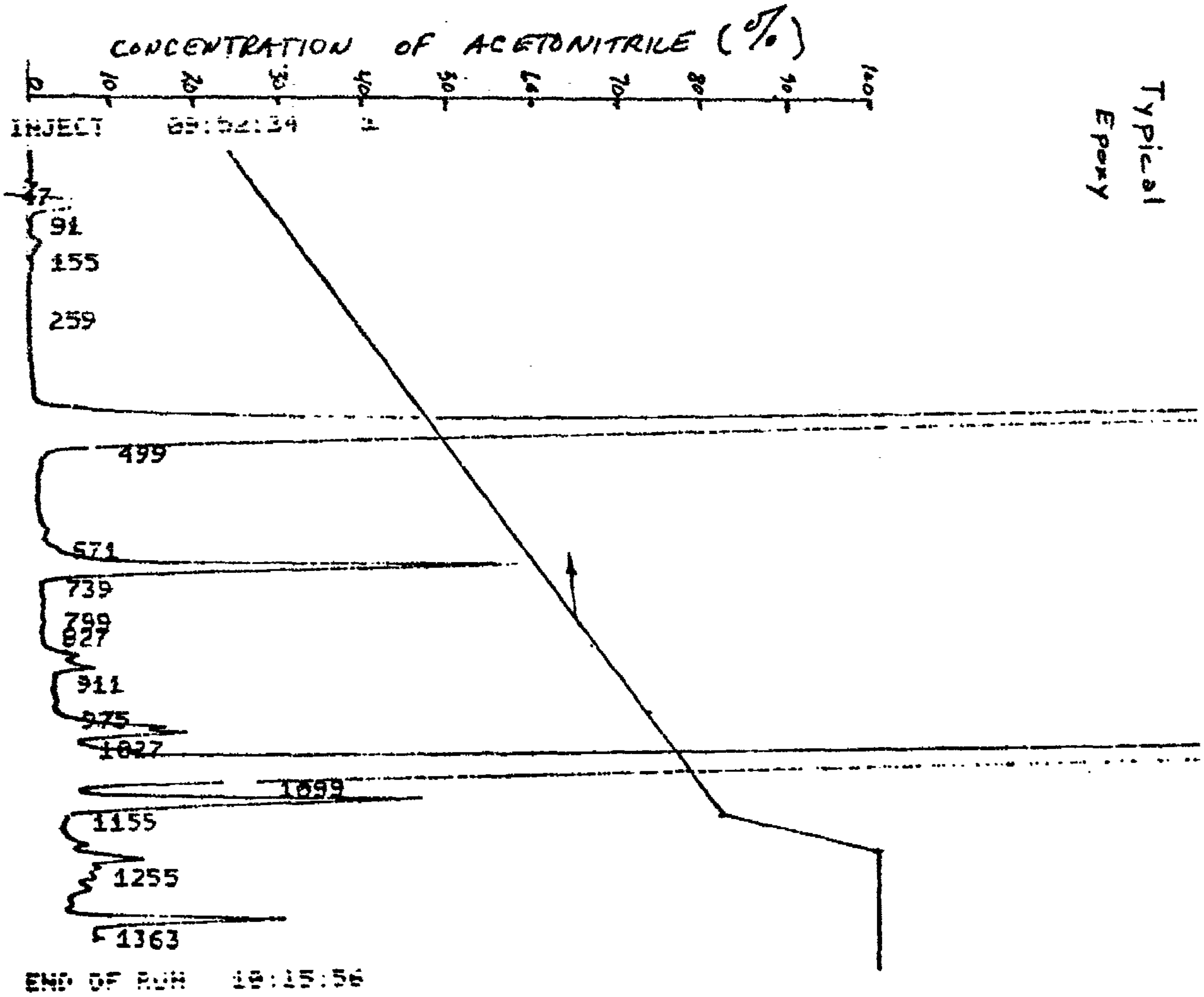


Figure 26. HPLC Analysis of Epon 828 Epoxy Resin.

TABLE 21

TENSILE PROPERTIES OF SiC/5506 COMPOSITE LAMINATES

Composite Material Properties

Material System - SiC/5506
Fiber - 5.6 mil SiC Matrix - AVCO 5506
Maximum Rated Temperature - 350°F (177°C)
Resin Content - 18.8% by wt.
Fiber Content - 59.9% by vol.
Void Content - 0.3% by vol.
Thickness of each type specimen: 0° - 6 ply ; 90° - 15 ply

Prepreg by - AVCO
Laminate Sp. Gr. - 2.38
Nominal Ply Thickness - 0.0062 inch
No. of panels from which specimens were tested in this table - 6

SiC/Epoxy

TENSION: 0°

	-67°F (-55°C)	72°F (22°C)	260°F (127°C)	350°F (177°C)
F_x^{tu} [ksi] (MPa)	[221.6] (1527)	[229.1] (1578)	[190.6] (1313)	[174.5] (1202)
Stnd. Dev. [ksi] (MPa)	[18.2] (125)	[8.4] (58)	[13.3] (92)	[11.0] (76)
Range [ksi] (MPa)	[198.8 - 235.8] (1370 - 1625)	[220.3 - 241.7] (1518 - 1665)	[178.8 - 205.0] (1232 - 1412)	[161.7 - 181.0] (1114 - 1247)
No. of Specimens	5	5	3[1]	3[1]
F_x^{tpl} [ksi] (MPa)	[129.5] (892)	[71.4] (492)	[86.7] (59)	[57.4] (395)
Stnd. Dev. [ksi] (MPa)	[36.2] (249)	[20.4] (141)	[12.5] (86)	[19.5] (134)
No. of Specimens	5	5	3	3
E_x^t [Msi] (GPa)	[32.3] (223)	[33.4] (230)	[33.2] (229)	[33.0] (227)
Stnd. Dev. [Msi] (GPa)	[1.1] (7.6)	[1.3] (9.0)	[0.4] (2.8)	[2.4] (1.7)
No. of Specimens	5	5	3	3
ϵ_x^{tu} [μin/in] (μcm/cm)	7600	7660	6800	5130+[2]
Stnd. Dev.	190	760	---	N.A.
No. of Specimens	5	5	2	3
ν_{xy}^t	0.22	0.23	0.25	0.32
Stnd. Dev.	0.03	0.02	0.05	0.15
No. of Specimens	5	4	3	3
Test Method Reference	ASTM D3039			

TENSION: 90°

	-67°F (-55°C)	72°F (22°C)	260°F (127°C)	350°F (177°C)
F_y^{tu} [ksi] (MPa)	[9.78] (67.4)	[9.71] (66.9)	[6.44] (44.4)	[4.34] (29.9)
Stnd. Dev. [ksi] (MPa)	[1.42] (9.78)	[0.51] (3.5)	[0.10] (0.7)	[0.40] (2.8)
Range	[8.31 - 11.55] (57.3 - 79.6)	[8.99 - 10.43] (61.9 - 71.9)	[6.34 - 6.56] (43.7 - 45.2)	[3.84 - 4.92] (26.5 - 33.9)
No. of Specimens	5	5	5	5
F_y^{tpl} [ksi] (MPa)	[6.17] (42.5)	[4.24] (29.2)	[2.84] (19.6)	[1.75] (12.1)
Stnd. Dev. [ksi] (MPa)	[1.21] (8.3)	[0.62] (4.3)	[0.17] (1.2)	[0.13] (0.9)
No. of Specimens	5	5	5	5
E_y^t [Msi] (GPa)	[3.86] (26.6)	[2.99] (20.6)	[1.97] (13.6)	[1.04] (7.2)
Stnd. Dev. [Msi] (GPa)	[0.12] (0.83)	[0.10] (0.69)	[0.16] (1.1)	[0.13] (0.9)
No. of Specimens	5	5	5	5
ϵ_y^{tu} [μin/in] (μcm/cm)	2,748	3,727	4,695	7,550
Stnd. Dev.	470	194	373	975
No. of Specimens	5	5	5	5
ν_{yx}^t	0.026[3]	0.021[3]	0.015[3]	0.010[3]
Stnd. Dev.				
No. of Specimens				
Test Method Reference	ASTM D3039			

[1] Excludes data from two specimens from bad panel (had very high void content).
[2] Strain gages failed before end of test on two of three specimens.
[3] Computed using elastic moduli and longitudinal Poisson's ratio.

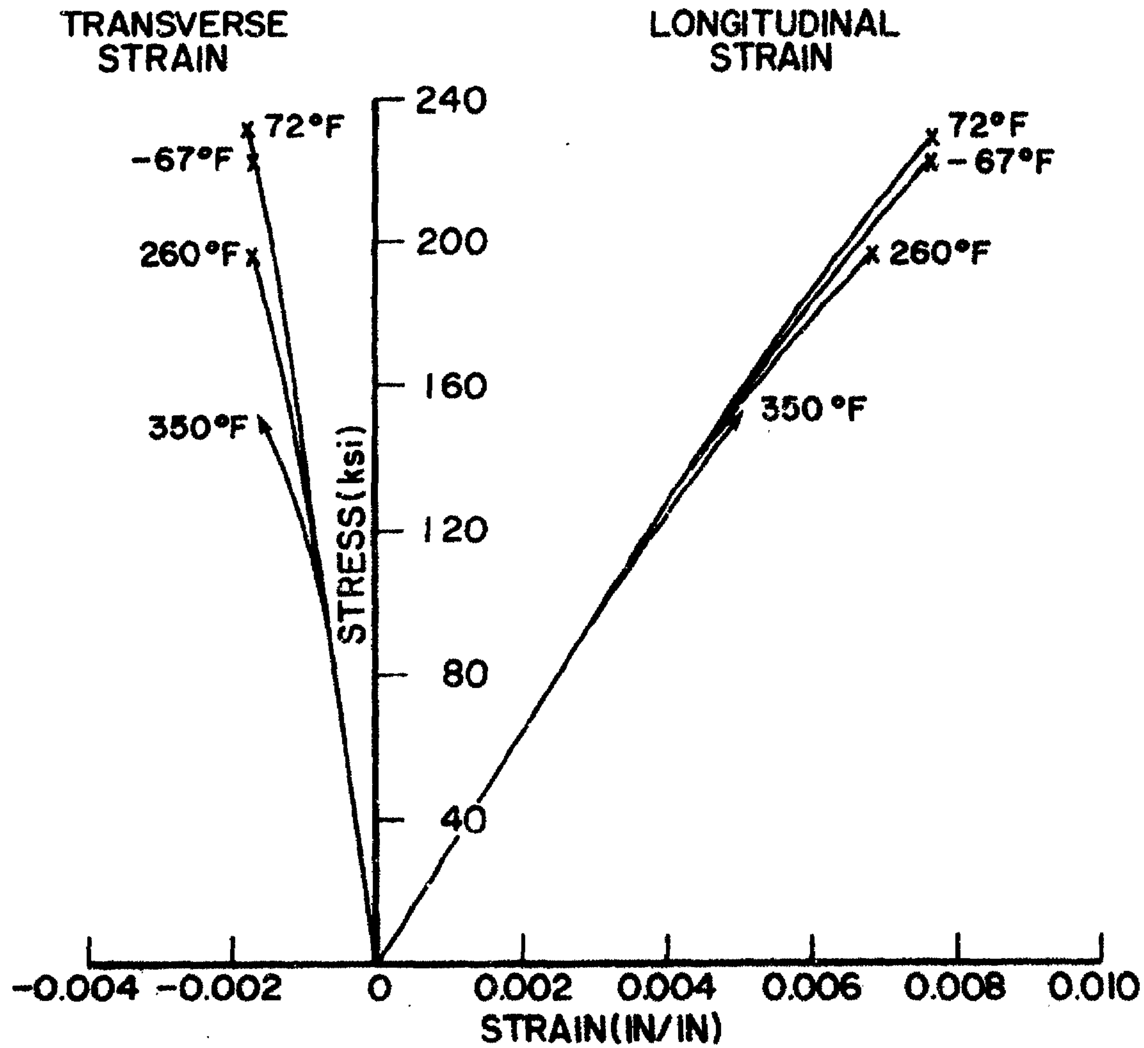


Figure 27. Tensile Stress-Strain Curves for Unidirectional SiC/5506 Composite Laminates: 0° Fiber Orientation.

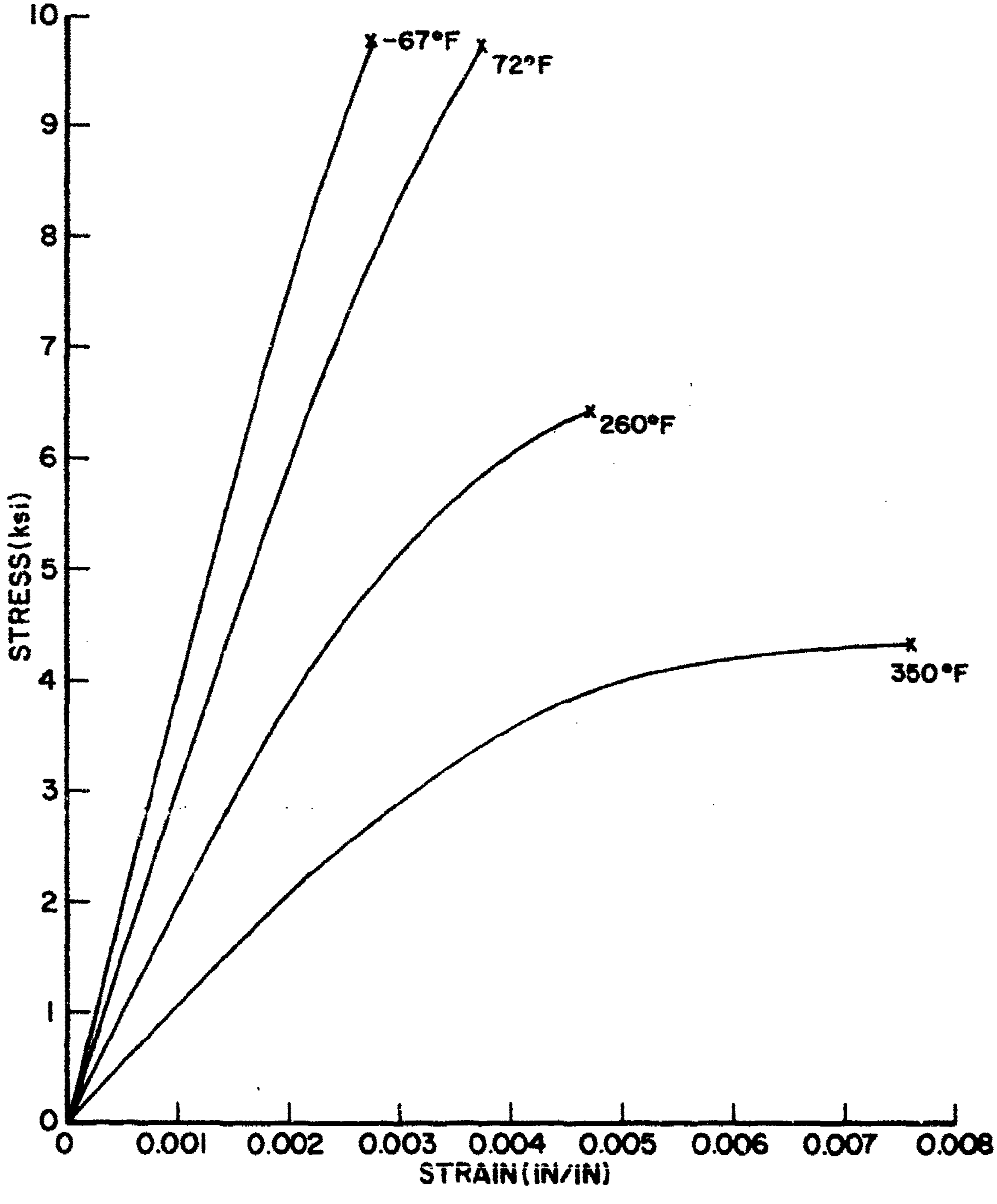


Figure 28. Tensile Stress-Strain Curves for Unidirectional SiC/5506 Composite Laminates: 90° Fiber Orientation.

TABLE 22

TENSILE PROPERTIES OF SiC/5506 COMPOSITE LAMINATES

Composite Material Properties				
Material System - SiC/5506 Fiber - 5.6 mil SiC Matrix - AVCO 5506 Maximum Rated Temperature - 350°F(177°C) Resin Content - 20.2% by wt. Fiber Content - 56.8% by vol. Void Content - 0.7% by vol.	Prepreg by - AVCO Laminate Sp. Gr. - 2.33 Nominal Ply Thickness - 0.0064 inch No. of panels from which specimens were tested in this table - 4 Thickness of specimen - 8 ply	SiC/Epoxy		
TENSION: ±45°				
	-67°F(-55°C)	72°F(22°C)	260°F (127°C)	350°F (177°C)
F_x^{tu} [ksi](MPa)	[19.72] (135.9)	[17.32] (119)	[11.52] (79)	[7.93] (54.6)
Stnd.Dev. [ksi](MPa)	[1.19] (8.2)	[0.58] (4.0)	[0.34] (5.8)	[0.18] (1.2)
Range [ksi](MPa)	[17.69 - 20.63] (121.9 - 142.1)	[16.52-17.95] (114 - 124)	[10.66-12.45] (79 - 99)	[7.67 - 8.17] (52.8 - 56.3)
No. of Specimens	5	5	5	5
F_x^{tpl} [ksi](MPa)	[6.25] (43.1)	[5.14] (35)	[1.59] (11)	[0.93] (6.4)
Stnd.Dev. [ksi](MPa)	[0.57] (3.9)	[0.92] (6.3)	[0.37] (2.5)	[0.32] (2.2)
No. of Specimens	5	5	5	5
E_x^t [Msi](GPa)	[3.71] (25.6)	[2.97] (20)	[1.63] (11)	[0.51] (3.5)
Stnd.Dev. [Msi](GPa)	[0.22] (1.5)	[0.30] (2.1)	[0.27] (1.9)	[0.19] (1.3)
No. of Specimens	5	5	5	5
ε_x^{tu} [μin/in](μcm/cm)	8,600	15,510	35,100+[1]	30,900+[1]
Stnd. Dev.	1,234	544	7,280	6,540
No. of Specimens	5	5	5	5
ν_{xy}^t	0.66	0.74	0.89	0.74
Stnd. Dev.	0.07	0.08	0.11	0.11
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3039			

[1]Ultimate strain exceeded limits of strain gages.

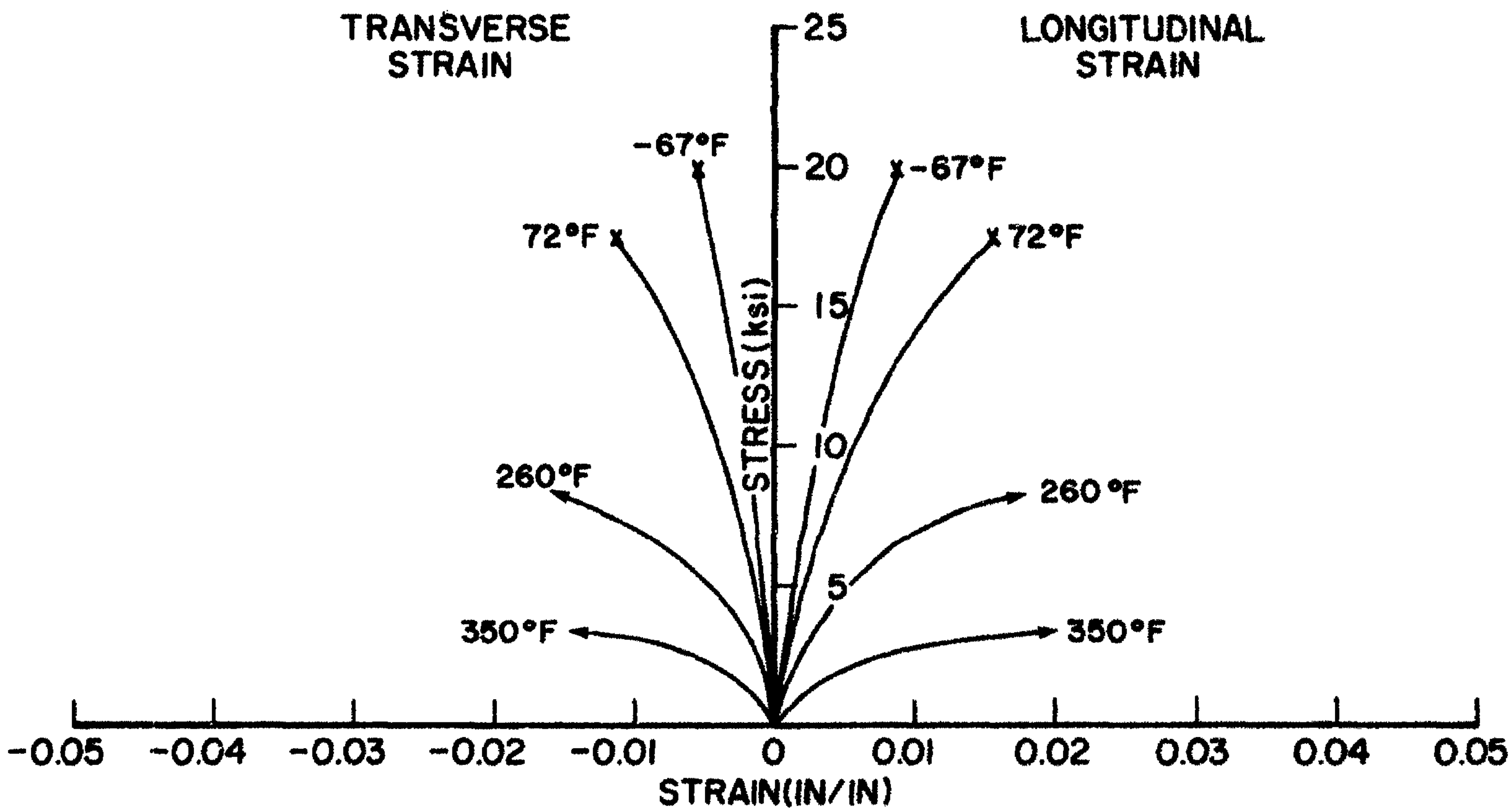


Figure 29. Tensile Stress-Strain Curves for Bidirectional SiC/5506 Composite Laminates: ±45° Fiber Orientation.

TABLE 23

TENSILE PROPERTIES OF SiC/5506
COMPOSITE LAMINATES

Composite Material Properties

Material System - SiC/5506
Fiber - 5.6 mil SiC Matrix - AVCO 5506
Maximum Rated Temperature - 350°F(177°C)
Resin Content - 10.9% by wt.
Fiber Content - 58.6% by vol.
Void Content - 0.9% by vol.
Thickness of each type specimen: 20 ply

Prepreg by - AVCO
Laminate Sp. Gr. - 2.35
Nominal Ply Thickness - 0.0062 inch
No. of panels from which specimens were tested in this table - 8

SiC/Epoxy

TENSION: $(0, +45, -45, 0, 0, -45, +45, 0, 90, 0)_s$

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{tu} [ksi](MPa)		[119.3] (822)	[117.2] (807)	[107.2] (739)
Stnd.Dev.[ksi](MPa)		[8.2] (56)	[7.7] (53)	[6.0] (41)
Range [ksi](MPa)		[108.2 - 125.6] (745 - 865)	[107.4-126.2] (740 - 870)	[102.1-115.6] (703 - 796)
No. of Specimens		4	5	4
F_x^{tpl} [ksi](MPa)		[38.6] (266)	[49.1] (338)	[60.3] (415)
Stnd.Dev.[ksi](MPa)		[18.8] (130)	[15.0] (103)	[11.1] (76)
No. of Specimens		5	5	4
E_x^t [Msi](GPa)		[20.5] (141)	[19.0] (131)	[18.1] (125)
Stnd.Dev.[Msi](GPa)		[2.0] (14)	[0.4] (2.8)	[0.6] (4)
No. of Specimens		5	5	4
ϵ_x^{tu} [μin/in](μcm/cm)		5725	5740	5190
Stnd.Dev.		100	100	670
No. of Specimens		4	5	4
ν_{xy}^t		0.31	0.45	0.40
Stnd. Dev.		0.10	0.11	0.06
No. of Specimens		4	5	4
Test Method Reference	ASTM D3039			

TENSION: $(0, +45, -45, 0, 0, -45, +45, 0, 90, 0)_s$ with hole[1]

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_y^{tu} [ksi](MPa)		[102.5] (706)		
Stnd.Dev.[ksi](MPa)		[3.5] (24)		
Range		[97.6-105.8] (672 - 729)		
No. of Specimens		5		
F_y^{tpl} [ksi](MPa)				
Stnd.Dev.[ksi](MPa)				
No. of Specimens				
E_y^t [Msi] (GPa)				
Stnd.Dev.[Msi] (GPa)				
No. of Specimens				
ϵ_y^{tu} [μin/in](μcm/cm)				
Stnd. Dev.				
No. of Specimens				
ν_{yx}^t				
Stnd. Dev.				
No. of Specimens				
Test Method Reference	ASTM D3039			

[1] These specimens had a 0.1935 inch (0.491 cm) hole in the center of the test section. Stresses were calculated using net cross-sectional area.

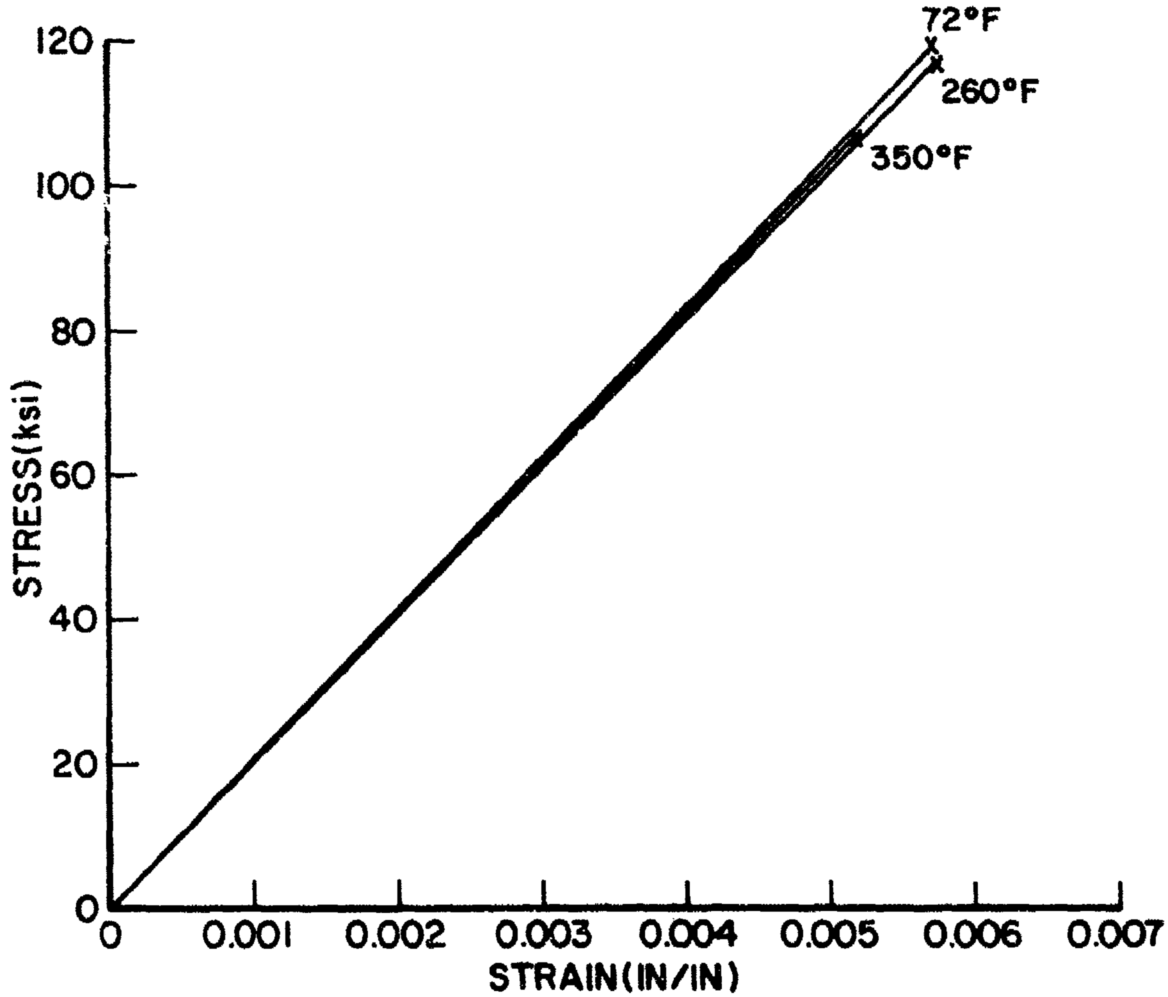


Figure 30 . Tensile Stress-Strain Curves for Multidirectional SiC/5506 Composite Laminates: $(0,45,-45,0,0,-45,45,0,90,0)_s$ Fiber Orientation.

TABLE 24

COMPRESSIVE PROPERTIES OF SiC/5506 COMPOSITE LAMINATES

Composite Material Properties

Material System - SiC/5506	Prepreg by - AVCO — SiC/Epoxy
Fiber - 5.6 mil SiC Matrix - AVCO 5506	Laminate Sp. Gr. - 2.38
Maximum Rated Temperature - 350°F (177°C)	Nominal Ply Thickness - 0.0061 inch
Resin Content - 18.5% by wt.	No. of panels from which specimens were tested in this table - 1
Fiber Content - 59.7% by vol.	
Void Content - 0.1% by vol.	
Thickness of each type specimen: 0° - 16 ply ; 90° - 16 ply	

COMPRESSION: 0°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{cu} [ksi](MPa)	[391] (2694)	[326] (2246)	[232] (1598)	[131] (903)
Stnd.Dev.[ksi](MPa)	[36] (248)	[20] (138)	[8] (55)	[29] (200)
Range [ksi](MPa)	[335 - 435] (2308 - 2997)	[305 - 350] (2101 - 2412)	[221 - 240] (1523 - 1654)	[97 - 154] (668 - 1061)
No. of Specimens	5	5	5	5
F_x^{cpl} [ksi](MPa)	[239] (1647)	[117] (806)	[141] (1269)	[95] (655)
Stnd.Dev.[ksi](MPa)	[65] (448)	[61] (420)	[32] (220)	[9] (62)
No. of Specimens	5	3	5	5
E_x^c [Msi](GPa)	[33.1] (228)	[35.5] (245)	[33.9] (233)	[34.0] (234)
Stnd.Dev.[Msi](GPa)	[3.0] (21)	[2.8] (19)	[3.2] (22)	[8.0] (55)
No. of Specimens	5	5	5	5
ε_x^{cu} [μin/in](μcm/cm)	12,920+[1,2]	6,220+[3]	7,760	3,560+[1,2]
Stnd. Dev.	4,310	1,730	1,110	300
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3410			

COMPRESSION: 90°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_y^{cu} [ksi](MPa)	[56.7] (391)	[34.4] (237)	[25.7] (177)	[19.8] (136)
Stnd.Dev.(ksi](MPa)	[3.6] (25)	[1.7] (12)	[1.5] (10)	[1.2] (8)
Range	[53.4-62.3] (368-429)	[31.8-36.3] (219-250)	[23.0-26.9] (158-185)	[18.7-21.6] (129-149)
No. of Specimens	5	5	5	5
F_y^{cpl} [ksi](MPa)	[15.5] (107)	[18.0] (124)	[14.3] (99)	[9.4] (65)
Stnd.Dev.[ksi](MPa)	[7.1] (49)	[9.1] (63)	[3.2] (22)	[2.2] (15)
No. of Specimens	5	5	5	5
E_y^c [Msi](GPa)	[3.41] (23.5)	[3.58] (24.7)	[2.40] (16.5)	[1.88] (13.0)
Stnd.Dev.[Msi](GPa)	[0.97] (6.7)	[0.60] (4.1)	[0.12] (0.8)	[0.32] (2.2)
No. of Specimens	5	5	5	5
ε_y^{cu} [μin/in](μcm/cm)	22,200	9,240+[4]	20,540+[1,2]	27,100
Stnd. Dev.	3,340	4,820	3,620	3,070
No. of Specimens	5	5	5	4
Test Method Reference	ASTM D3410			

[1] Ultimate strain values represent ~~maximum observed~~ strain rather than ultimate values.

[2] Two of five specimens exhibited evidence of buckling.

[3] Tabs debonded during first test attempt at about 65% of ultimate strength. Tabs were rebonded with a different adhesive and the tests were rerun. Modulus and proportional limit were obtained from data recorded during first test. Ultimate strain values could not be obtained during second test because of strain gage damage when first set of tabs debonded. Value reported represents strain when tabs debonded on first test.

[4] Three of five specimens exhibited evidence of buckling.

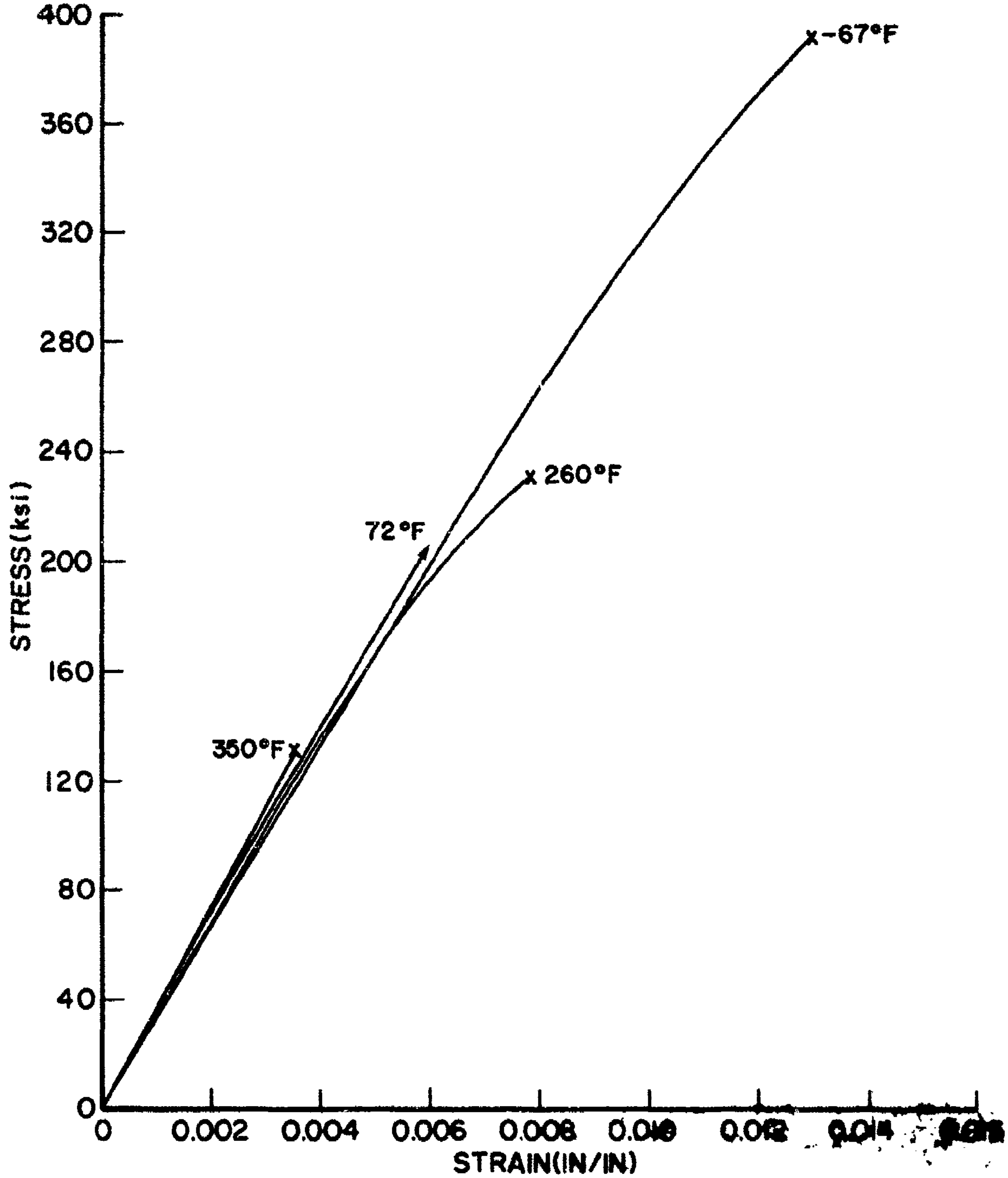


Figure 31. Compressive Stress-Strain Curves for Undirectional SiC/5506 Composite Laminates: 0° Fiber Orientation.

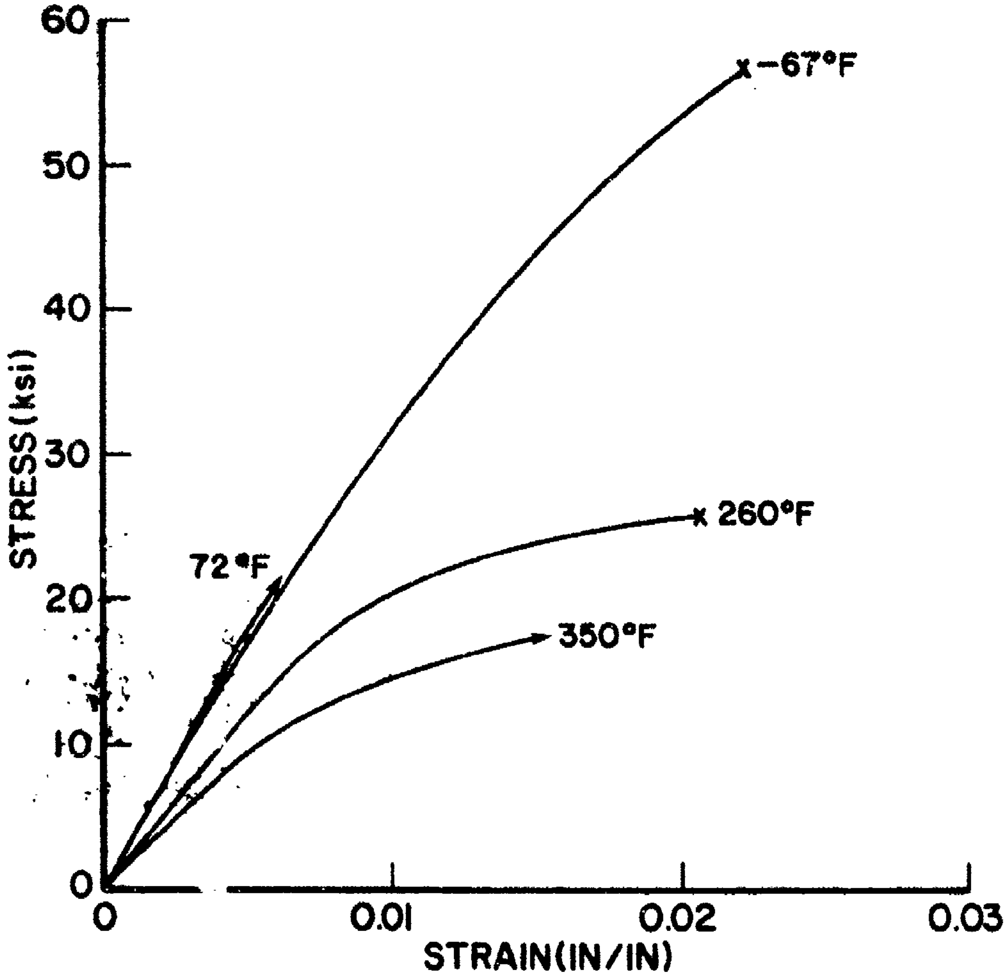


Figure 32. Compressive Stress-Strain Curves for Unidirectional SiC/5506 Composite Laminates: 90° Fiber Orientation.

TABLE 25

FLEXURAL PROPERTIES OF SiC/5506
COMPOSITE LAMINATES

Composite Material Properties				
Material System - SiC/5506 Fiber - 5.6mil SiC Matrix - AVCO 5506 Maximum Rated Temperature - 350°F(177°C) Resin Content - 19.4% by wt. Fiber Content - 58.9% by vol. Void Content - ≐ 0% by vol. Thickness of each type specimen: 0° - 14 ply ; 90° - 14 ply	Prepreg by - AVCO Laminate Sp. Gr. - 2.37 Nominal Ply Thickness - 0.0069 inch No. of panels from which specimens were tested in this table ≐ 2		SiC/Epoxy	
FLEXURE: 0°				
	-67°F(-55°C)	72°F(22°C)	260°F (127°C)	350°F (177°C)
F_x^{fu} [ksi](MPa)	[324.9] (2239)	[314.6] (2168)	[189.3] (1304)[1,2]	[120.0] (827)[1,2]
Stnd.Dev. [ksi](MPa)	[8.1] (56)	[10.1] (69.6)	[21.6] (148)	[6.5] (45)
Range [ksi](MPa)	[317.9-336.4] (2190-2318)	[298.0-324.1] (2053-2233)	[166.1-217.2] (1144-1497)	[109.9-126.2] (757-870)
No. of Specimens	5	5	5	5
E_x^f [Msi](GPa)	[31.9] (220)	[31.8] (219)	[29.6] (204)	[30.4] (209)
Stnd.Dev. [Msi](GPa)	[0.71] (4.9)	[0.48] (3.3)	[0.94] (6.5)	[1.8] (12)
No. of Specimens	5	5	5	5
Test Method Reference	4 pt. flexure Design Guide; Jan. 1971	} Corresponds to ASTM D790 except for loading points and loading speed		
FLEXURE: 90°				
F_y^{fu} [ksi](MPa)	[15.86] (109)	[14.53] (100)	[11.08] (76)	[6.96] (48)[2]
Stnd.Dev. [ksi](MPa)	[1.3] (8.9)	[0.78] (5.4)	[1.35] (9.3)	[0.63] (4.3)
Range [ksi](MPa)	[14.94-17.26] (103-119)	[13.45-15.53] (93-107)	[9.96-13.21] (69-91)	[6.09-7.74] (42-53)
No. of Specimens	5	5	5	5
E_y^f [Msi](GPa)	[2.71] (19)	[2.34] (16)	[1.44] (9.9)	[0.85] (5.9)
Stnd.Dev. [Msi](GPa)	[0.18] (1.2)	[0.13] (0.9)	[0.18] (1.2)	[0.03] (0.2)
No. of Specimens	5	5	5	5
Test Method Reference	4 pt. flexure Design Guide; Jan. 1971	} Corresponds to ASTM D790 except for loading points and loading speed		

[1]Specimens underwent abnormally large deformations and exhibited interlaminar shear failure rather than tensile failure on bottom ply.

[2]See following table for flexure properties using a three-point loading mode.

TABLE 26

FLEXURAL PROPERTIES OF SiC/5506
COMPOSITE LAMINATES

Composite Material Properties				
Material System - SiC/5506 Fiber - 5.6 mil SiC Matrix - AVCO 5506 Maximum Rated Temperature - 350°F Resin Content - 17.4% by wt. Fiber Content - 61.1% by vol. Void Content - 0.5% by vol. Thickness of each type specimen: 0° - 14 plies 90° - 14 plies		Prepreg by - AVCO Laminate Sp. Gr. - 2.41 Nominal Ply Thickness - 0.0061 inch No. of panels from which specimens were tested in this table - 1		SiC/Epoxy
FLEXURE: 0°				
	-67°F(-55°C)	72°F(22°C)	260°F (127°C)	350°F (177°C)
F_x^{fu} [ksi](MPa)			[316.7] (2182)	[175.5] (1209)[1]
Stnd.Dev. [ksi](MPa)			[7.2] (49)	[5.4] (37)
Range [ksi](MPa)			[308.7-322.9] (2127-2225)	[173.8-182.9] (1197-1260)
No. of Specimens			4	4
E_x^f [Msi](GPa)			[29.0] (200)	[24.6] (169)
Stnd.Dev. [Msi](GPa)			[0.9] (6)	[0.8] (6)
No. of Specimens			4	4
Test Method Reference	ASTM D790, Method 1 (3 pt. flexure)			
FLEXURE: 90°				
F_y^{fu} [ksi](MPa)				[9.89] (68)
Stnd.Dev. [ksi](MPa)				[1.51] (10)
Range [ksi](MPa)				[8.20-11.30] (56-78)
No. of Specimens				4
E_y^f [Msi](GPa)				[1.03] (7.1)
Stnd.Dev. [Msi](GPa)				[0.11] (0.8)
No. of Specimens				4
Test Method Reference	ASTM D790, Method 1 (3 pt. flexure)			

[1] Specimens failed by interlaminar shear rather than tensile failure on bottom ply.

TABLE 27

SHEAR PROPERTIES OF SiC/5506 COMPOSITE LAMINATES

Composite Material Properties

Material System - SiC/5506	Prepreg by - AVCO — SiC/Epoxy
Fiber - 5.6 mil SiC Matrix - AVCO 5506	Laminate Sp. Gr. - 2.33
Maximum Rated Temperature - 350°F(177°C)	Nominal Ply Thickness - 0.0064 inch
Resin Content - 18.3% by wt.	No. of panels from which specimens were tested in this table - 4
Fiber Content - 60.1% by vol.	
Void Content - ≈0	
Thickness of each type specimen: Inplane - 8 ply ; Interlaminar - 15 ply	

INPLANE SHEAR

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F^{su}_{xy} [ksi] (MPa)	[9.86] (67.9)	[8.66] (59.7)	[5.76] (39.5)	[3.97] (27.3)
Stnd.Dev. [ksi] (MPa)	[0.60] (4.1)	[0.29] (4.0)	[0.42] (2.9)	[0.09] (0.6)
Range [ksi] (MPa)	[8.85 - 10.32] (60.9 - 71.1)	[8.26 - 8.98] (56.9 - 61.9)	[5.33 - 6.23] (39.5 - 49.5)	[3.83 - 4.09] (26.4 - 28.2)
No. of Specimens	5	5	5	5
G^{s}_{xy} [Msi] (GPa)	[1.07] (7.37)	[0.74] (5.10)	[0.36] (2.46)	[0.14] (0.98)
Stnd.Dev. [Msi] (GPa)	[0.003] (0.02)	[0.06] (0.41)	[0.04] (0.25)	[0.03] (0.21)
No. of Specimens	5	5	5	5
Test Method Reference	±45° straight-sided tension J. Composite Mtls. [Vol. 6, p. 252 & Vol. 7, p. 124]			

INTERLAMINAR SHEAR

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F^{isu} [ksi] (MPa)	[21.3] (147)	[15.0] (103)	[9.1] (63)	[8.0] (55)
Stnd.Dev. [ksi] (MPa)	[0.2] (1.4)	[0.2] (1.4)	[0.3] (2.1)	[0.4] (2.8)
Range	[21.1 - 21.7] (145 - 150)	[14.8 - 15.3] (102 - 105)	[8.8 - 9.6] (61 - 66)	[7.5 - 8.6] (52 - 59)
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D2344			

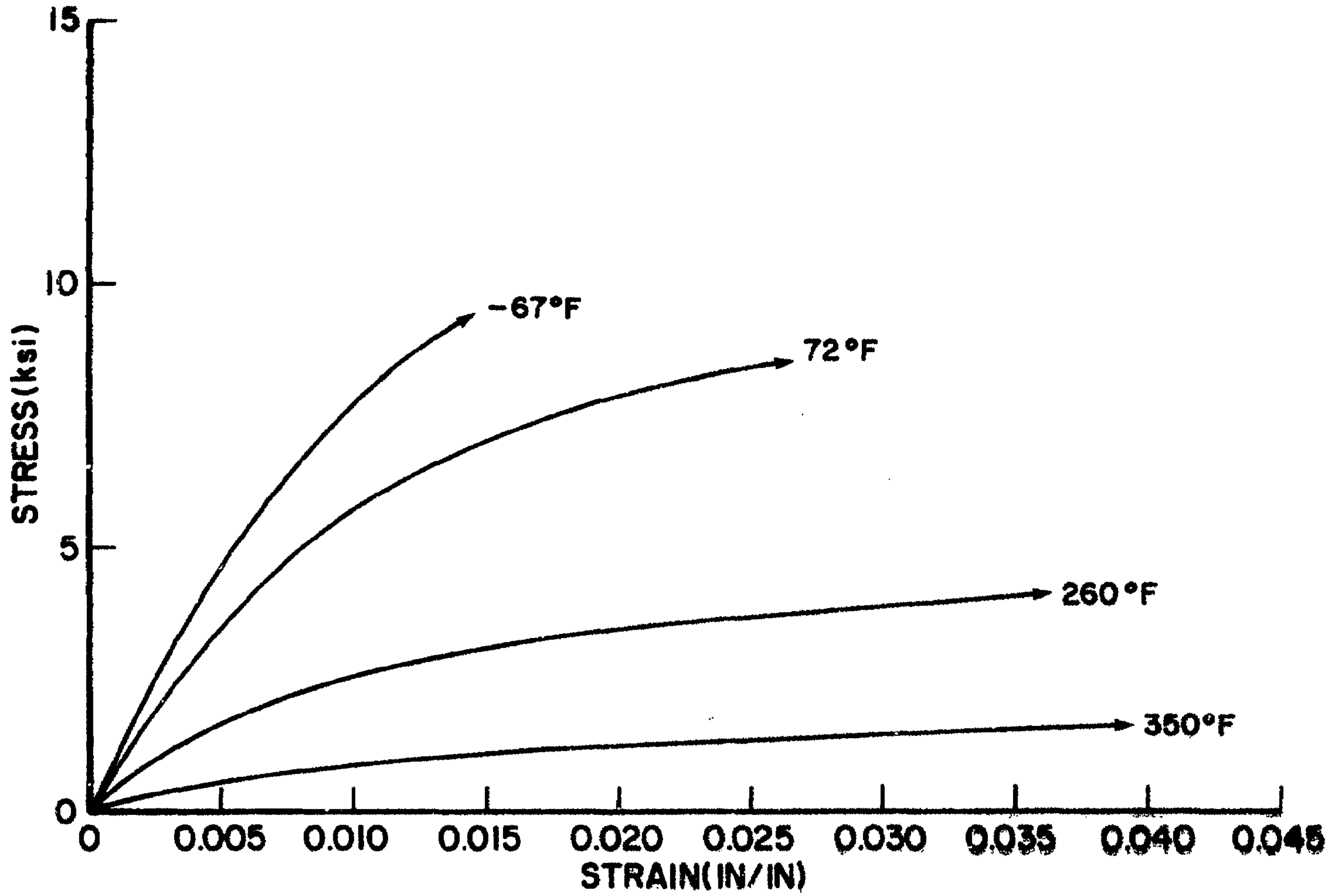


Figure 33. Inplane Shear Stress-Strain Curves for SiC/5506 Composite Laminates.

TABLE 28

TENSILE, COMPRESSIVE AND SHEAR PROPERTIES OF SiC/5506 COMPOSITE LAMINATES AFTER HUMIDITY AGING

Composite Material Properties

SiC/Epoxy

Material System - SiC/5506   Prepreg by - AVCO
Fiber - 5.6 mil SiC   Matrix - AVCO 5506   Laminate Sp. Gr. - 2.38
Maximum Rated Temperature - 350°F   Nominal Ply Thickness - 0.0062 inch
Resin Content - 18.8% by wt.(177°C)   No. of panels from which specimens were tested in this table - 7
Fiber Content - 59.5% by vol.
Void Content - 0.3% by vol.   Aging Conditions - 160°F(71°C)&100% R.H.
Thickness of each type specimen: Tension - 15 ply; Compr. - 16 ply; Shear - 15 ply

TENSION: 90°

	72°F(22°C)	260°F(127°C)	72°F(22°C)	260°F(127°C)
Exposure Time (hrs)	1546	1546	175	175
Wt. Gain(% of orig. dry wt.)	1.26[1]	1.26[1]	0.59	0.60
Stnd. Dev.(%)	0.03	0.05	0.02	0.02
No. of Specimens	5	5	5	5
F_y^{tu} [ksi](MPa)	[6.18](42.6)	[1.93](13.3)	[8.77](60.4)	[3.82](26.3)
Stnd. Dev. [ksi](MPa)	[0.69](4.8)	[0.17](1.2)	[0.51] (3.5)	[0.36] (2.5)
Range [ksi](MPa)	[5.02-6.81] (34.6-46.9)	[1.75-2.19] (12.2-15.1)	[8.20-9.50] (56.5-65.5)	[3.29-4.27] (22.7-29.4)
No. of Specimens	5	5	5	5
F_y^{tpl} [ksi](MPa)	[2.58](17.8)	[0.68](4.7)	[2.26](15.6)	[0.81] (5.6)
Stnd. Dev. [ksi](MPa)	[0.80](5.5)	[0.10](0.7)	[0.38](2.6)	[0.22] (1.5)
No. of Specimens	5	5	5	5
E_y^c [Msi](GPa)	[2.58](17.8)	[0.75](5.2)	[3.08](21.2)	[1.11] (7.6)
Stnd. Dev. [Msi](GPa)	[0.19](1.3)	[0.28](1.9)	[0.23] (1.6)	[0.16] (1.1)
No. of Specimens	5	5	5	5
ϵ_y^{tu} [μin/in](μcm/cm)	2763	5007	3417	7640
Stnd. Dev.	258	1074	307	786
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3039			

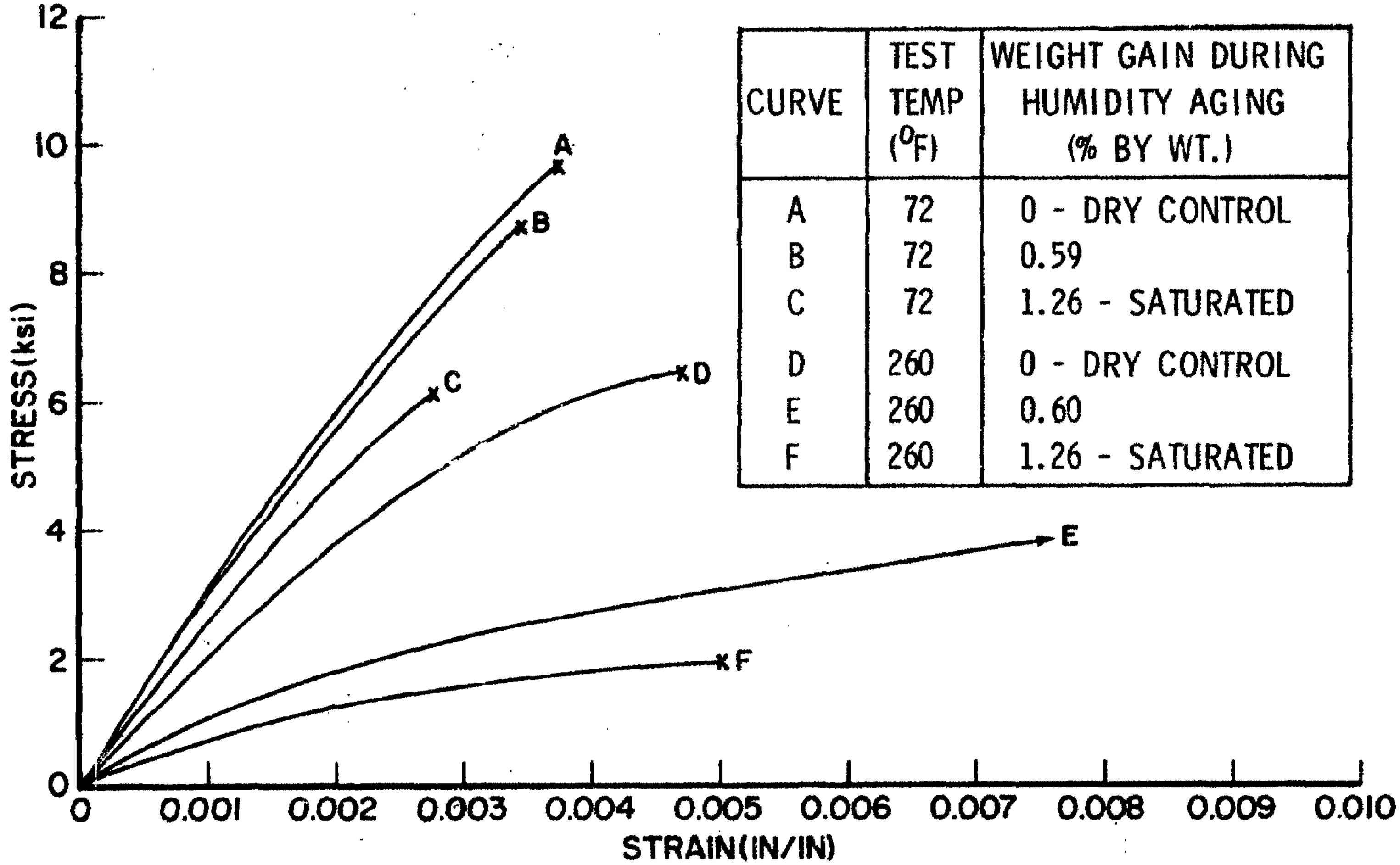
COMPRESSION: 90°

	72°F(22°C)	260°F(127°C)	72°F(22°C)	260°F(127°C)
Exposure Time(hrs)	1752	1752	162.5	162.5
Wt. Gain(% of orig. dry wt.)	1.31[1]	1.31[1]	0.76	0.79
Stnd. Dev. (%)	0.08	0.12	0.07	0.03
No. of Specimens	4	5	5	5
F_y^{cu} [ksi](MPa)	[24.5](169)	[17.7](122)	[29.5](203)	[18.8](130)
Stnd. Dev. [ksi](MPa)	[0.8] (6)	[1.8] (12)	[1.7](12)	[0.9](6)
Range	[23.8-25.7] (164-177)	[15.6-19.0] (107-131)	[26.9-31.4] (185-216)	[17.5-19.8] (121-136)
No. of Specimens	5	5	5	5
F_y^{cpl} [ksi](MPa)	[10.3](71)	[11.0](76)	[7.6] (52)	[5.7] (39)
Stnd. Dev. [ksi](MPa)	[3.8] (26)	[2.7] (19)	[6.2] (43)	[1.4] (10)
No. of Specimens	5	5	5	5
E_y^c [Msi](GPa)	[2.85](20)	[3.32](23)	[4.19](29)	[3.01](21)
Stnd. Dev. [Msi](GPa)	[0.6] (4)	[0.8] (6)	[0.8](6)	[0.7](5)
No. of Specimens	5	5	5	5
ϵ_y^{cu} [μin/in](μcm/cm)	20,480	11,150[3]	32,209[4]	10,620[5]
Stnd. Dev.	6,650	7,230	800	9,470
No. of Specimens	5	5	3	5
Test Method Reference	ASTM D3410			

INTERLAMINAR SHEAR

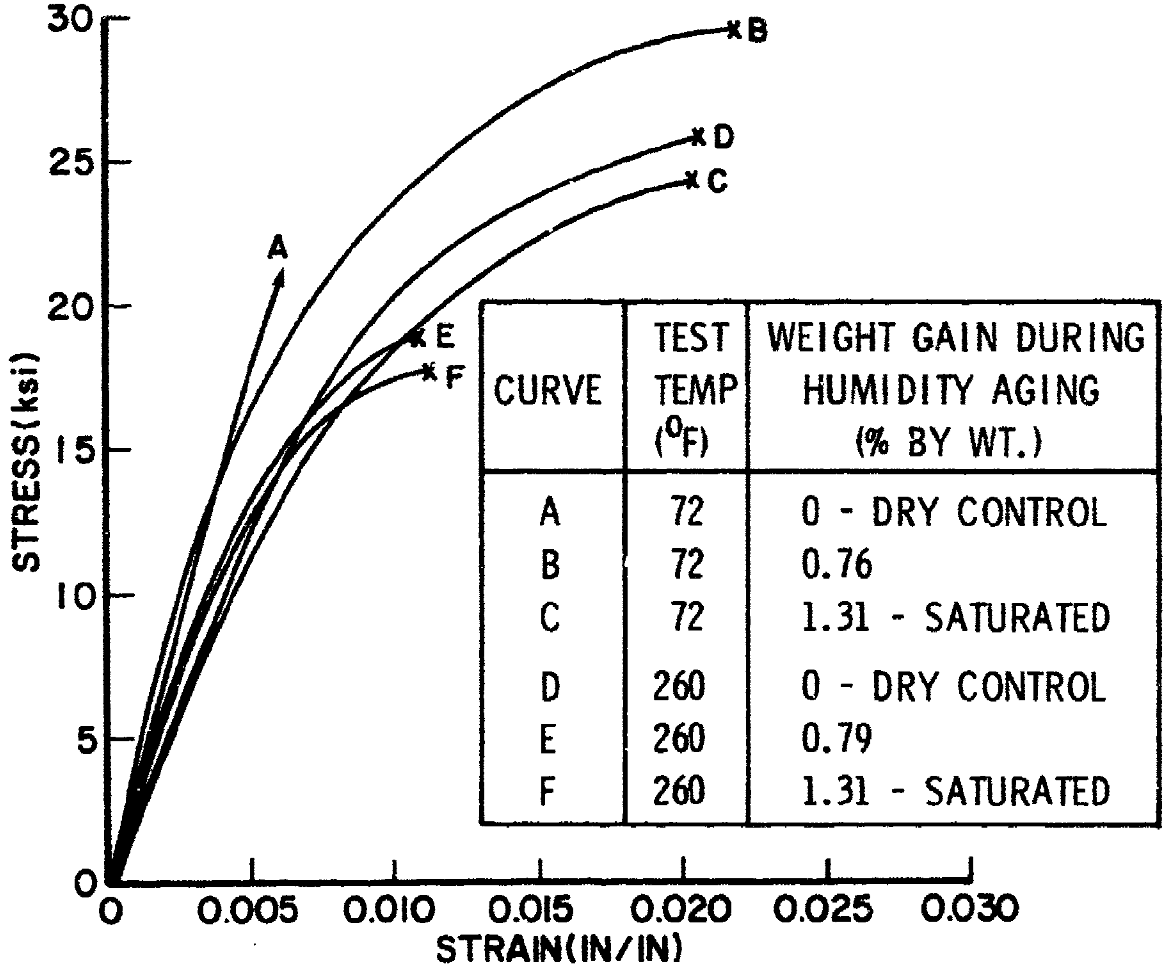
	72°F(22°C)	260°F(127°C)	72°F(22°C)	260°F(127°C)
Exposure Time(hrs)	240	335	384[2]	384[2]
Wt. Gain(% of orig. dry wt.)	1.07[1]	1.09[1]	0.63	0.67
Stnd. Dev. (%)	0.31	0.21	0.09	0.14
No. of Specimens	10	5	10	5
F^{isu} [ksi](MPa)	[12.06](83.1)	[7.15] (49.3)	[11.61](80.0)	[6.79](46.8)
Stnd. Dev. [ksi](MPa)	[0.70](6.3)	[0.13] (0.9)	[0.33] (2.3)	[0.30](2.1)
Range [ksi](MPa)	[10.74-12.59] (74.0-86.7)	[7.01-7.31] (48.3-50.4)	[11.07-12.06] (76.3-83.1)	[6.30-7.00] (43.4-48.2)
No. of Specimens	10	5	10	5
Test Method Reference	ASTM D2344			

NOTES:
[1] 100% saturation at aging conditions.
[2] Chamber malfunctioned during aging. Total exposure time required to reach 0.65% weight gain does not reflect the normal time required to gain this amount of moisture for a small interlaminar shear specimen.
[3] Ultimate strain value represents maximum observed strain rather than ultimate values. Evidence of buckling on one specimen.
[4] Excludes two specimens which exhibited evidence of buckling.
[5] Ultimate strain value represents maximum observed strain rather than ultimate values. Evidence of buckling on all five specimens.



CURVE	TEST TEMP (^{o}F)	WEIGHT GAIN DURING HUMIDITY AGING (% BY WT.)
A	72	0 - DRY CONTROL
B	72	0.59
C	72	1.26 - SATURATED
D	260	0 - DRY CONTROL
E	260	0.60
F	260	1.26 - SATURATED

Figure 34. Tensile Stress-Strain Curves for Unidirectional SiC/5506 Composite Laminates After Humidity Aging at 160°F (71°C) and 100% R.H.: 90° Fiber Orientation.



CURVE	TEST TEMP (^{0}F)	WEIGHT GAIN DURING HUMIDITY AGING (% BY WT.)
A	72	0 - DRY CONTROL
B	72	0.76
C	72	1.31 - SATURATED
D	260	0 - DRY CONTROL
E	260	0.79
F	260	1.31 - SATURATED

Figure 35. Compressive Stress-Strain Curves for Unidirectional SiC/5506 Composite Laminates After Humidity Aging at 160°F (71°C) and 100% R.H.: 90° Fiber Orientation.

TABLE 29

CREEP PROPERTIES OF SiC/5506 COMPOSITE LAMINATES

Composite Material Properties

SiC/Epoxy

Material System - SiC/5506
Fiber - 5.6 mil SiC   Matrix - AVCO 5506
Maximum Temperature Rating - 350°F(177°C)
Resin Content - 19.2% by wt.
Fiber Content - 58.0% by vol.
Void Content - 1.1% by vol.

Test Method - Straight-sided tension
Reference - ASTM D2290 and D3039

Prepreg by - AVCO

Laminate Sp. Gr. - 2.34
Nominal Ply Thickness - 0.0065 inch
No. of panels from which specimens were tested in this table - 16
Thickness of each type specimen:
(0/±45/90)$_s$ - 20 ply
±45°- 8 ply

CREEP

Temperature		(0,+45,-45,0,0,-45,+45,0,90,0)$_s$	±45°
72°F(22°C)	Stress Level [ksi](MPa)	[83.5] (575)	[13.86] (95.50)
	Creep Strain, 500 hr(%)	0.0121	1.0280
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[105.3](726)	[16.[illegible]3] (117)
	No. of Specimens	3	3
	Stress Level [ksi](MPa)	[71.6] (493)	[12.13] (83.58)
	Creep Strain, 500 hr(%)	0.0102	0.5312
	No. of Specimens	2	3
	Residual Strength[ksi](MPa)	[102.7](708)	[17.24] (119)
	No. of Specimens	2	3
	Stress Level [ksi](MPa)	[59.6] (411)	[10.39] (71.59)
	Creep Strain, 500 hr(%)	0.0070	0.4480
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[102.5](706)	[17.3[illegible]] (119)
	No. of Specimens	3	3
260°F(127°C)	Stress Level [ksi](MPa)	[82.0] (565)	[8.07] (55.60)
	Creep Strain, 500 hr(%)	0.0313[6]	---[1]
	No. of Specimens	1	---
	Residual Strength[ksi](MPa)	[106.6](734)	[17.86] (123)
	No. of Specimens	3	1
	Stress Level [ksi](MPa)	[70.3] (484)	[5.76] (39.69)
	Creep Strain, 500 hr(%)	0.0180	3.2171[2]
	No. of Specimens	1[5,7]	2
	Residual Strength[ksi](MPa)	[101.4](699)	[15.87] (109)
	No. of Specimens	2	3
	Stress Level [ksi](MPa)	[58.6] (404)	[5.12] (35.28)
	Creep Strain, 500 hr(%)	0.0216	1.3228[2]
	No. of Specimens	3	2
	Residual Strength[ksi](MPa)	[105.6](728)	[16.57] (114)
	No. of Specimens	3	3
350°F(177°C)	Stress Level [ksi](MPa)	[60.4] (416)	[3.17] (21.84)
	Creep Strain, 500 hr(%)	0.0674	---[3]
	No. of Specimens	1[5,7]	3
	Residual Strength[ksi](MPa)	[94.1] (648)	---
	No. of Specimens	2	0
	Stress Level [ksi](MPa)		[1.59] (10.96)
	Creep Strain, 500 hr(%)		---[4]
	No. of Specimens		3
	Residual Strength[ksi](MPa)		[15.68] (108)
	No. of Specimens		2
	Stress Level [ksi](MPa)		[1.19] (8.20)
	Creep Strain, 500 hr(%)		---[4]
	No. of Specimens		3
	Residual Strength[ksi](MPa)		[15.35] (106)
	No. of Specimens		3

NOTES: [1]Strain exceeded limits of gages early in test. Two specimens failed during test.
[2]Strain exceeded gage limit during test on one specimen.
[3]All three specimens failed within first ten minutes.
[4]Strain exceeded limits of gages early in test.
[5]One specimen failed on loading.
[6]Strain gages malfunctioned on two specimens.
[7]Strain gage malfunctioned on one specimen.

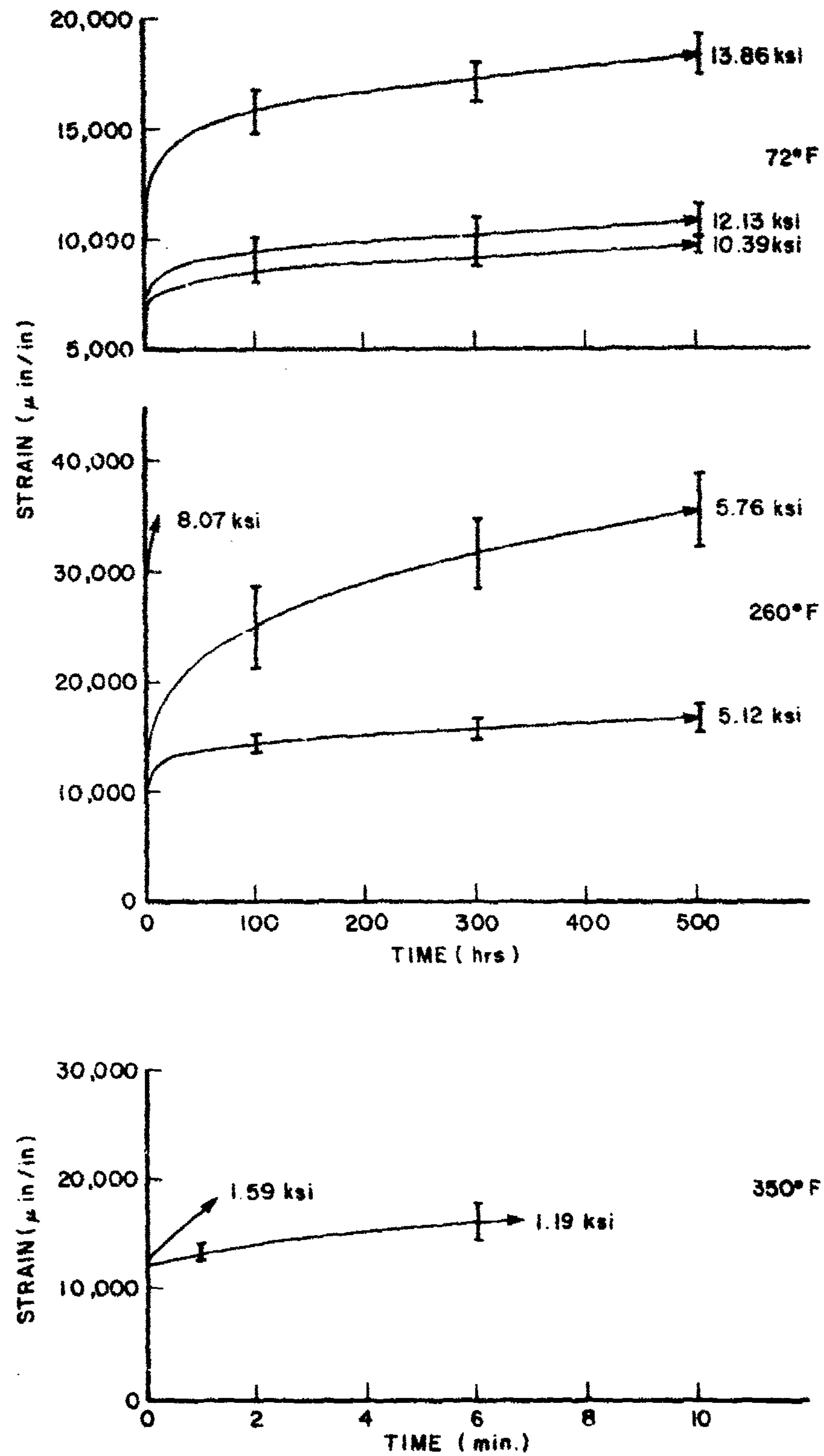


Figure 36. Tensile Creep Behavior of Bidirectional SiC/5506 Composite Laminates: ±45° Fiber Orientation.

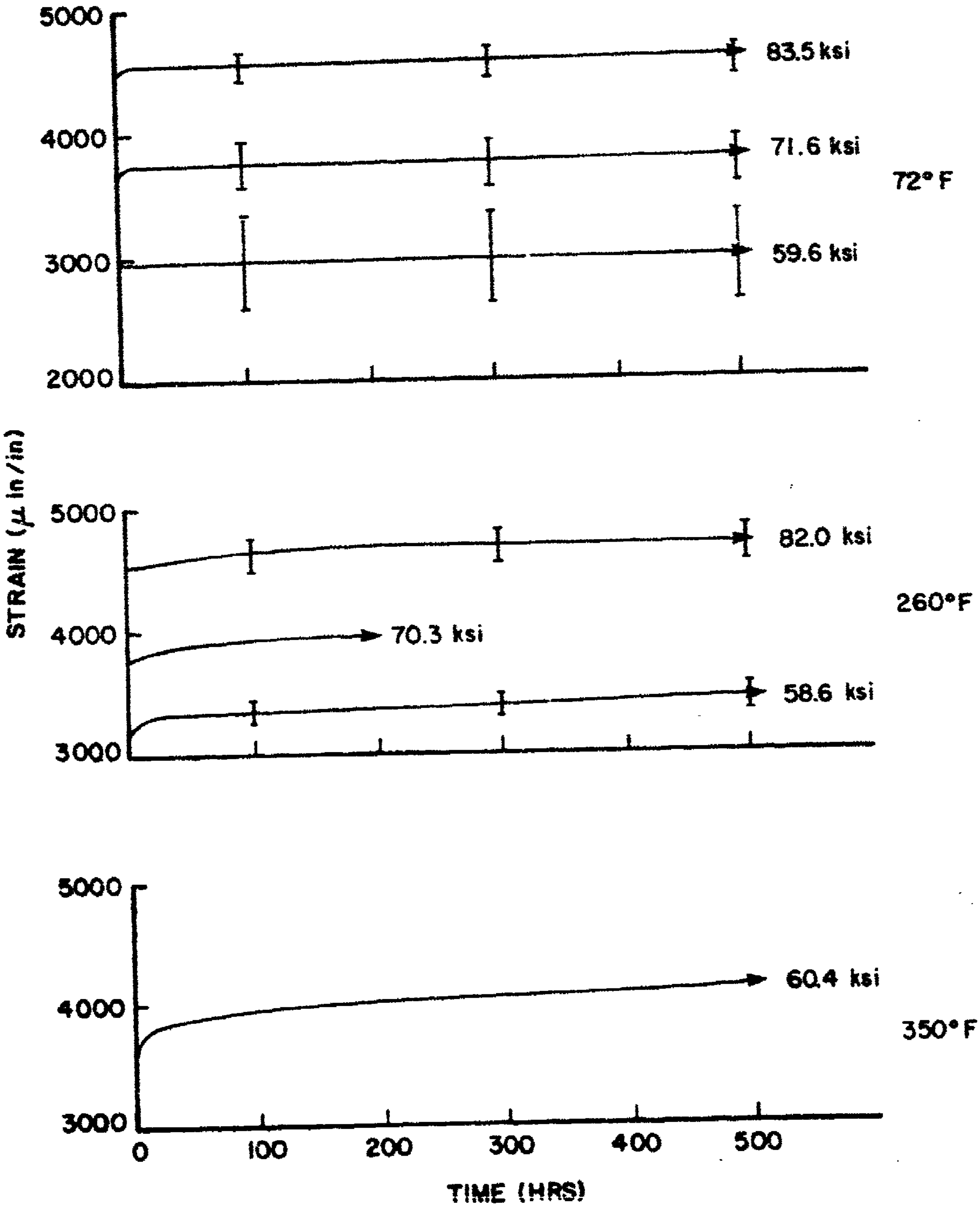


Figure 37. Tensile Creep Behavior of SiC/5506 Composite Laminates: $(0,+45,-45,0,0,-45,+45,0,90,0)_s$ Fiber Orientation.

TABLE 30

STRESS RUPTURE PROPERTIES OF SiC/5506
COMPOSITE LAMINATES

Composite Material Properties			
Material System - SiC/Epoxy Fiber - 5.6 mil SiC Matrix - AVCO 5506 Maximum Temperature Rating - 350°F(177°C) Resin Content - 19.2% by wt. Fiber Content - 58.0% by vol. Void Content - 1.1% by vol. Test Method - Straight-sided tension Reference - ASTM D2290 and D3039		Prepreg by - AVCO Laminate Sp. Gr. - 2.34 Nominal Ply Thickness - 0.0065 inch No. of panels from which specimens were tested in this table - 16 Thickness of each type specimen: (0/±45/90) - 20 ply ±45 - 8 ply	SiC/5506
STRESS RUPTURE			
Temperature	Fiber Orientation	$(0,+45,-45,0,0,-45,+45,0,90,0)_s$	±45°
72°F (22°C)	Stress Level[ksi](MPa)	[83.5] (575)	[13.86] (95.50)
	Time to Failure(hrs)	500+	500+
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[105.3] (726)	[16.93] (117)
	No. of Specimens	3	3
	Stress Level[ksi](MPa)	[71.6] (493)	[12.13] (83.58)
	Time to Failure(hrs)	500+	500+
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[102.7] (708)	[17.24] (119)
	No. of Specimens	3	3
260°F(127°C)	Stress Level[ksi](MPa)	[82.0] (565)	[8.07] (55.6)
	Time to Failure(hrs)	500+	202+[1]
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[106.6] (734)	[17.86] (123.1)
	No. of Specimens	3	1
	Stress Level[ksi](MPa)	[70.3] (484)	[5.76] (39.7)
	Time to Failure(hrs)	500+	500+
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[101.4] (699)	[15.87] (109.3)
	No. of Specimens	2	3
350°F(177°C)	Stress Level[ksi](MPa)	[60.4] (416)	[3.17] (21.8)
	Time to Failure(hrs)	500+	0.08
	No. of Specimens	2	3
	Residual Strength[ksi](MPa)	[94.1] (648)	---
	No. of Specimens	2	0
	Stress Level[ksi](MPa)		[1.59] (11.0)
	Time to Failure(hrs)		346+[2]
	No. of Specimens		3
	Residual Strength[ksi](MPa)		[15.68] (108.0)
	No. of Specimens		2

[1]One specimen survived for 500 hrs. without failure.
[2]Two specimens survived for 500 hrs. without failure.

TABLE 31

FATIGUE PROPERTIES OF SiC/5506
COMPOSITE LAMINATES

Composite Material Properties

Material System - SiC/5506
Fiber - 5.6 mil SiC Matrix - AVCO 5506
Maximum Temperature Rating - 350°F(177°C)
Resin Content - 19.2% by wt.
Fiber Content - 58.1% by vol.
Void Content - 1.0% by vol.
Test Method - Straight-sided tension Reference - ASTM D3039

Prepreg by - AVCO

SiC/Epoxy

Laminate Sp. Gr. - 2.34
Nominal Ply Thickness - 0.0066 inch
No. of panels from which specimens were tested in this table - 17
Thickness of each type specimen:
±45° - 8 ply
0/±45/90 - 20 ply

TENSILE FATIGUE, R=0.1

Temperature	Fiber Orientation	±45°	0/±45/90 (1)	0/±45/90 (1,2)
72°F(22°C)	Max. Stress[ksi](MPa)	[12.12] (83.5)	[77.5] (534)	[83.3] (574)
	Lifetime (cycles)	3,534	11,644	7,237 (3)
	No. of Specimens	5	5	4
	Residual Strength[ksi](MPa)	---	---	---
	No. of Specimens	0	0	0
	Max. Stress[ksi](MPa)	[9.53] (65.7)	[65.6] (452)	[75.0] (517)
	Lifetime (cycles)	94,974 (3)	475,439 (3)	114,479
	No. of Specimens	4	4	5
	Residual Strength[ksi](MPa)	---	---	---
	No. of Specimens	0	0	0
	Max. Stress[ksi](MPa)	[7.79] (53.7)	[59.6] (411)	[62.5] (431)
	Lifetime (cycles)	2,663,831	3,463,243	1,895,681 (3)
	No. of Specimens	4	5	4
	Residual Strength[ksi](MPa)	---	---	---
	No. of Specimens	0	0	0
260°F(127°C)	Max. Stress[ksi](MPa)	[8.06] (55.5)	[70.3] (484)	
	Lifetime (cycles)	2,118	3,110	
	No. of Specimens	5	5	
	Residual Strength[ksi](MPa)	---	---	
	No. of Specimens	0	0	
	Max. Stress[ksi](MPa)	[6.34] (43.7)	[64.5] (444)	
	Lifetime (cycles)	75,744 (3)	111,073 (3)	
	No. of Specimens	4	4	
	Residual Strength[ksi](MPa)	---	---	
	No. of Specimens	0	0	
	Max. Stress[ksi](MPa)	[5.76] (39.7)	[58.6] (404)	
	Lifetime (cycles)	10^7+ (3)	346,552 (3)	
	No. of Specimens	1	4	
	Residual Strength[ksi](MPa)	[14.6] (100)	---	
	No. of Specimens	1	0	

NOTES: 1. Stacking sequence was (0, +45, -45, 0, 0, -45, +45, 0, 90, 0)s.

2. These specimens had a 0.1935 inch (0.491 cm) hole in the center of the test section. Stresses calculated using net cross-sectional area.

3. Excludes data for one specimen from bad panel.

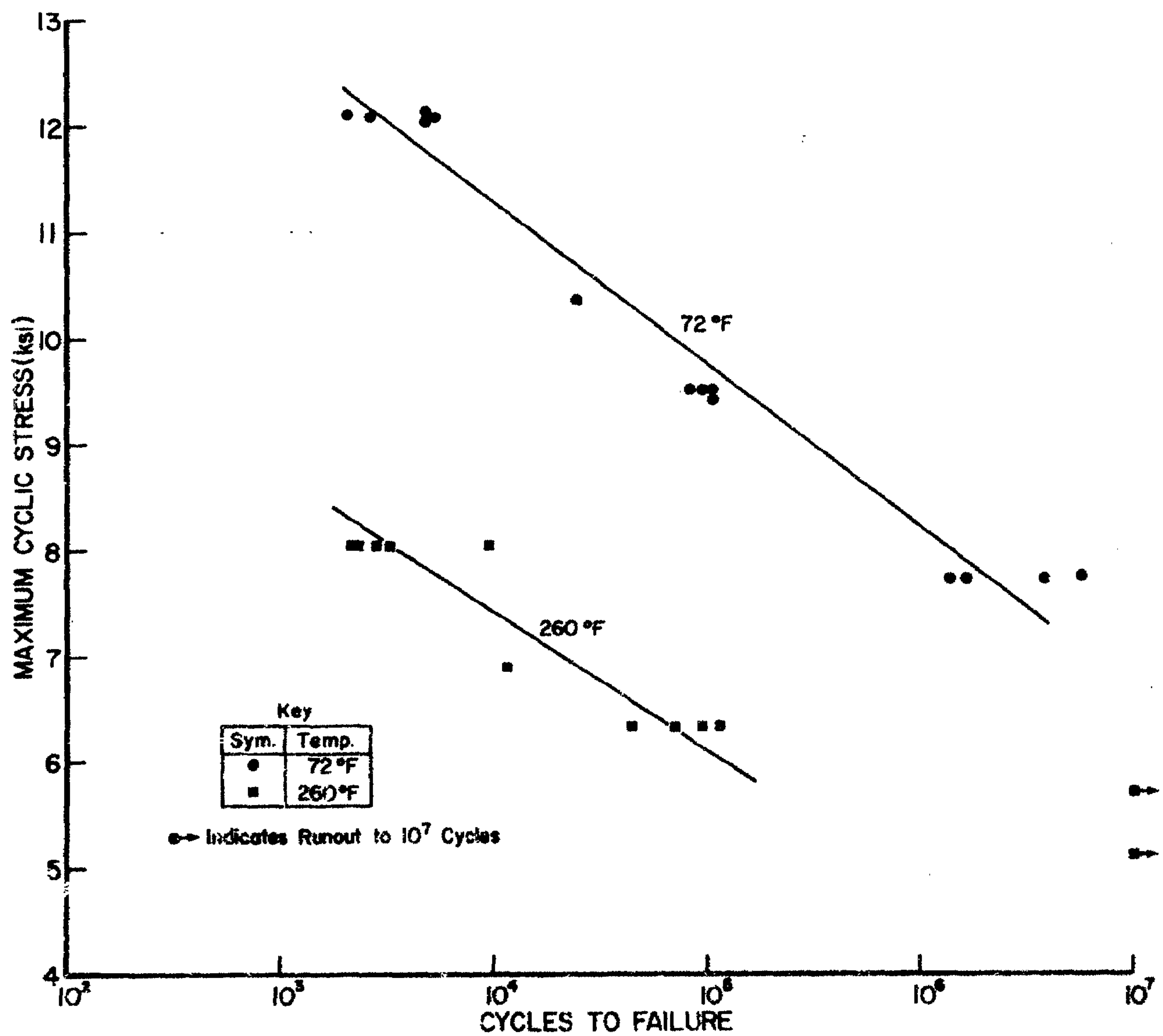


Figure 38. Tensile-Tensile Fatigue Behavior of Bidirectional SiC/5506 Composite Laminates: $\pm 45°$ Fiber Orientation, R = 0.10, 10 Hz.

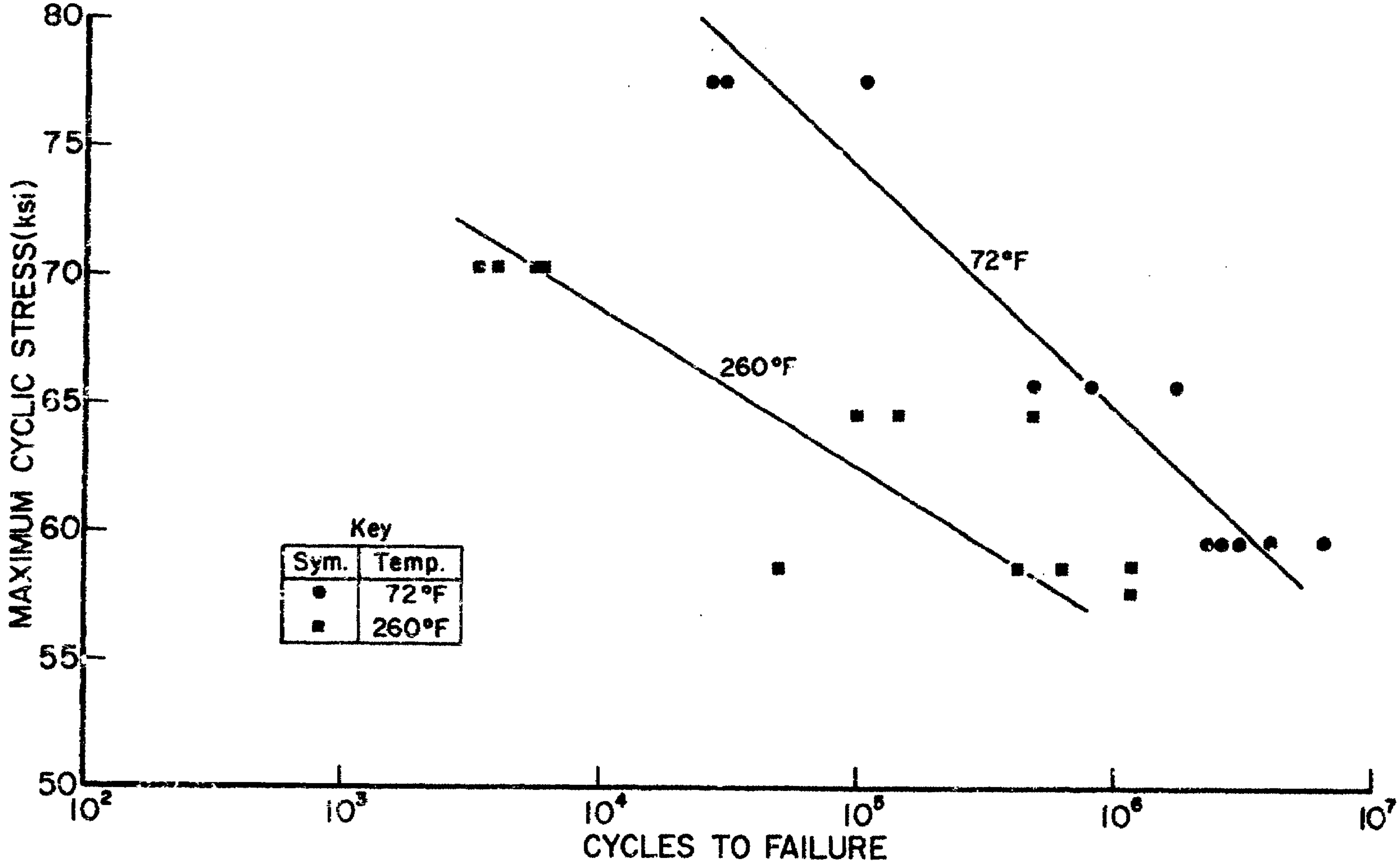


Figure 39. Tensile-Tensile Fatigue Behavior of Multidirectional SiC/5506 Composite Laminates: $(0,45,-45,0,0,-45,45,0,90,0)_s$ Fiber Orientation, R = 0.10, 10 Hz.

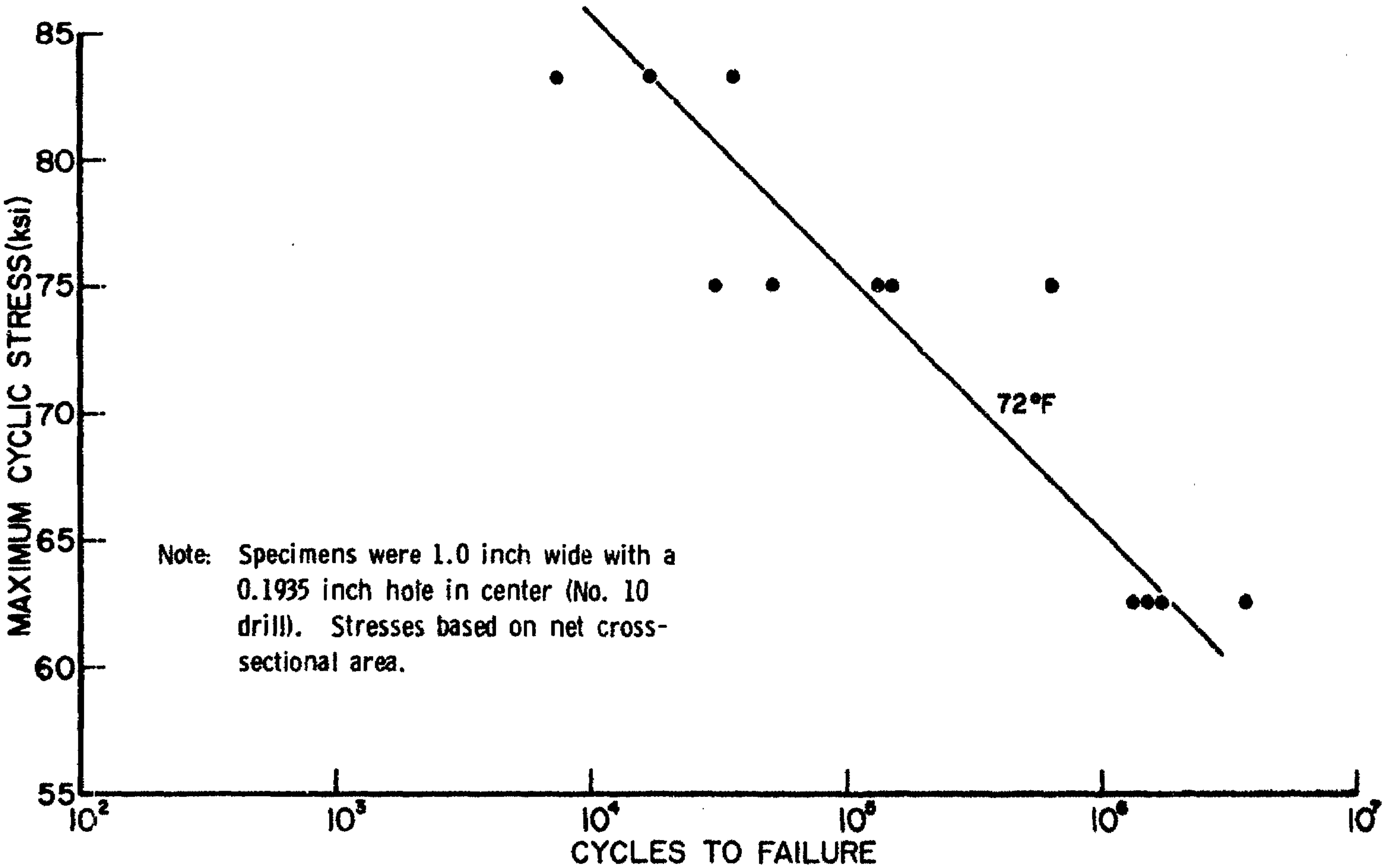


Figure 40. Tensile-Tensile Fatigue Behavior of Multidirectional SiC/5506 Composite Laminates: $(0,45,-45,0,0,-45,45,0,90,0)_s$ Fiber Orientation, R = 0.10, 10 Hz.

TABLE 32

THERMOPHYSICAL PROPERTIES OF SiC/5506
COMPOSITE LAMINATES

Composite Material Properties

Material System - SiC/5506	Prepreg by - AVCO
Fiber - 5.6 mil SiC Matrix - AVCO 5506	SiC/Epoxy
Maximum Temperature Rating - 350°F(177°C)	Laminate Sp. Gr. - 2.35
Resin Content - 19.1% by wt.	Average Ply Thickness - 0.0065 inch
Fiber Content - 58.4% by vol.	No. of panels from which specimens were tested in this table - 4
Void Content - 1.0% by vol.	
Thickness of each type specimen:	Spec. Ht. - 1 ply
Therm. Exp. 0° & 90° - 40 ply, ± 45° - 8 ply; Therm. Cond. - 40 ply	Glass Trans. - 8 plies

THERMOPHYSICAL PROPERTIES: 0°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)	Test Method
Thermal Expansion[1]					
α_x [μin/in-°F] (μcm/cm-°C)	[1.34] (2.41)	[1.56] (2.81)	[2.01] (3.62)	[2.23] (4.02)	TMA[2]
α_y [μin/in-°F] (μcm/cm-°C)	[7.89] (14.2)	[9.56] (17.2)	[18.8] (33.9)	[37.8] (68.1)	
No. of Specimens per direction	3	3	3	3	
Specific Heat					
C_p [btu/lb.-°F] (J/kg-°C)	[0.186] (778)	[0.221] (924)	[0.279] (1170)	[0.309] (1292)	DSC[3]
No. of Specimens	3	3	3	3	
Thermal Conductivity[1]					
k_z [btu-ft/ft^2-hr-°F] (W/m-°C)	[0.512] (0.885)	[0.572] (0.990)	[0.621] (1.074)	[0.615] (1.064)	Comparative
No. of Specimens	2	2	2	2	
Glass Transition Temp.					
Dry [°F] (°C)	[394] (201)				DMA[4]
Wet [°F] (°C)[5]	[293] (145)				

THERMOPHYSICAL PROPERTIES: ±45°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)	Test Method
Thermal Expansion[1]					
α_x [μin/in-°F] (μcm/cm-°C)	[2.83] (5.10)	[3.33] (6.00)	[3.52] (6.33)	[4.07] (7.32)	TMA[2]
No. of Specimens per direction	3	3	3	3	
Thermal Conductivity[1]					
k_z [btu-ft/ft^2-hr-°F] (W/m-°C)					
No. of Specimens					

NOTES: 1. On the unidirectionally reinforced specimens, the x-direction is along the fiber axis, the y-direction is across the fiber axis, and the z-direction is through the thickness (identical to the y-direction). On ±45° bidirectionally reinforced specimens, the x and y directions are identical and oriented at 45° to either fiber direction, while the z-direction is through the thickness.

2. Thermo-Mechanical Analysis.

3. Differential Scanning Calorimetry.

4. Dynamic Mechanical Analysis.

5. Specimen humidity aged to saturation at 160°F (71°C) and 100% R.H. prior to testing.

4.3 HyE 2034D

This graphite/epoxy system consists of a pitch-based graphite fiber (VSC-32) from Union Carbide in Fiberite's 934 epoxy resin system. The fiber has nominal tensile properties of 300 ksi (2067 MPa) strength, 75×10^6 psi (517 GPa) modulus and 0.4% elongation with a specific gravity of 2.05. It was given a finish treatment by Union Carbide to enhance its interfacial bonding to epoxy resins. The resin is a 350°F (177°C) curing epoxy system.

Tables 33 through 46 present the data generated for this graphite/epoxy system. Figures 41 through 57 illustrate the stress-strain, fatigue, and creep behavior of the material as well as the effects of humidity aging upon selected composite properties. In addition a preliminary data sheet, distributed by Fiberite, is presented at the end of the section with a few selected property values generated by various sources.

While the high modulus of the VSC-32 fiber is reflected in the composite properties, the static strength levels exhibited by this system are uniformly lower, and in most cases substantially lower, than those exhibited by the other five systems tested. This is probably due to a reduced level of interfacial fiber-to-resin bonding. The pitch based graphite reinforcing fiber in this system was given a finish treatment to enhance its bondability to the matrix resin but the treatment still does not appear to be capable of providing the level of interfacial bond strength which is achieved with the nominal 30 Msi (207 GPa) modulus PAN based graphite fibers used in the other systems (Thornel 300 or G-160).

TABLE 33

PROCESSING CONDITIONS FOR HyE2034D COMPOSITES

Composite Processing Information
Material System - HyE 2034D HMG/Epoxy Fiber - VSC-32 Matrix - 934 Maximum Rated Temperature - 350°F (177°C) Prepreg by - Fiberite
Laminate Processing Schedule
Layup Procedure: The prepreg was stored in a closed wrapper at 0°F (-18°C). Prepreg was warmed to room temperature before removal from wrapper to prevent moisture condensation on prepreg. Plies were cut to desired size with razor knife and stacked in desired sequence (release paper removed from each ply). The stack was placed in the autoclave according to the layup system illustrated in Figure 41. The corprene edge dam serves to restrict fiber flow.
Cure Schedule: Apply full vacuum and hold for 1/2 hour at room temperature. Heat to 250°F at a rate of 2-5°F/min. When temperature has reached 250°F apply 100 psi above bladder (while retaining vacuum). Hold at 250°F for 45 minutes then heat to 350°F at a rate of 2-5°F/min. Hold at 350°F for 2 hours then cool to 150°F at 2-5°F/min. Release pressure when temperature has reached 150°F, then release vacuum and remove panel from autoclave.
Postcure Schedule: None.

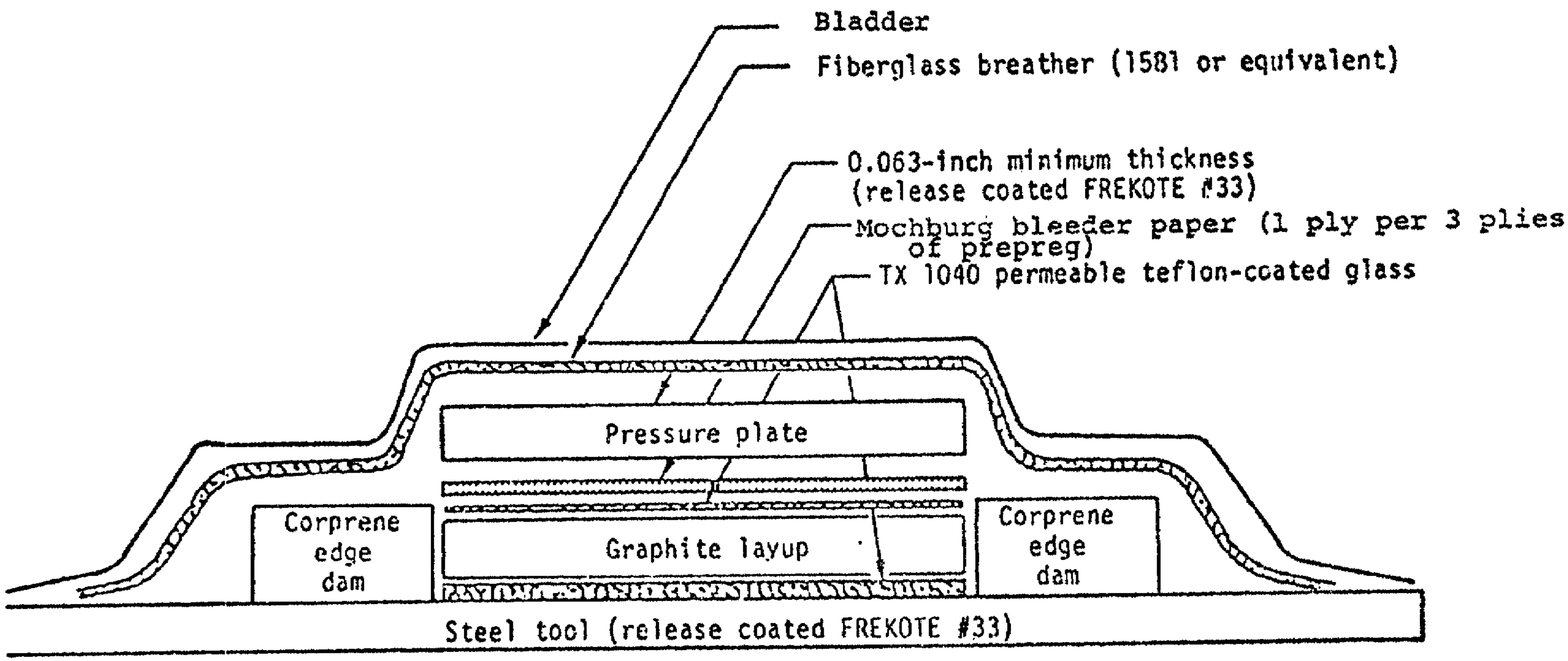


Figure 41. Layup System for HyE2034D Laminates.

TABLE 34

PREPREG AND COMPOSITE PHYSICAL PROPERTIES

Composite Physical Property Information				
Material System - HyE 2034D Fiber - VSC-32 Matrix - 934 Maximum Rated Temperature - 350°F(177°C)			HMG/Epoxy Prepreg by - Fiberite	
Prepreg Physical Properties				
(Property)	(Stnd.Dev.)	(Range)	(Test Method)	(Ref.)
Volatile Content- 0.67% by wt.	0.04%	0.62-0.69	QCI-C-V-14	Fiberite
Resin Content- 39.2% by wt.	0.9%	38.3-40.2	R15	Fiberite
Resin Flow- 22.4% by wt.	--	---	QCI-C-F-42	Fiberite
Gel Time - 12.45 min	0.20 min	12.23-12.63min	G2	Fiberite
No. of Rolls Involved - 1				
No. of Batches Involved - 1				
Laminate Physical Properties[1]				
	(Stnd.Dev.)	(Range)	(Test Method)	(Ref.)
No. of Panels- 33				
Fiber Content- 68.0% by vol.	1.5%	62.9-70.1%	Acid Digestion	
Resin Content- 24.5% by wt.	1.0%	23.0-27.0%	AFML-TR-67-243	
Void Content- ∿ 0			D2734	ASTM
Laminate Sp. Gr.- 1.80			D792	ASTM
Fiber Sp. Gr.- 2.00		As reported by	Fiberite.	
Matrix Sp. Gr.- 1.30		As reported by	Fiberite.	
Thickness per ply- 0.0049 inch			---	---

[1] The properties reported here represent averages for all panels of this material used throughout the program.

HPLC ANALYSIS

SAMPLE (CONC.) HYE- 2034D SAMPLE SIZE 15 mg/ml

MOBILE PHASE 1 Acetonitrile MOBILE PHASE 2 Water

FLOW RATE 2.0 ml/min PROGRAM Method ①

COLUMN(S) ODS DETECTOR Tracor 970

ATTENUATION 32 WAVE LENGTH 230 nm

CHART SPEED 0.5 cm/min FULL SCALE (mV) 20 mV

DATE November 30 79 OPERATOR Wolfe

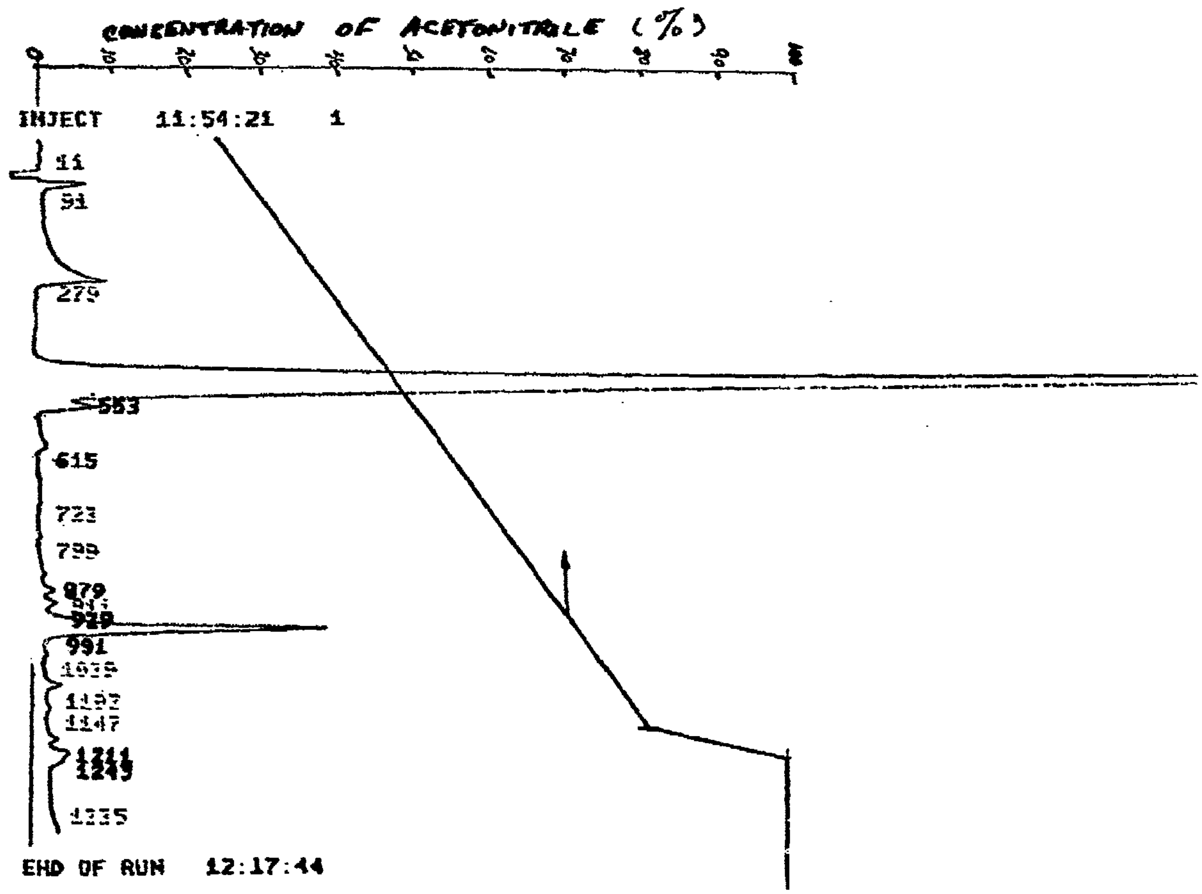


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Figure 42. HPLC Analysis of Fiberite 934 Epoxy Resin.

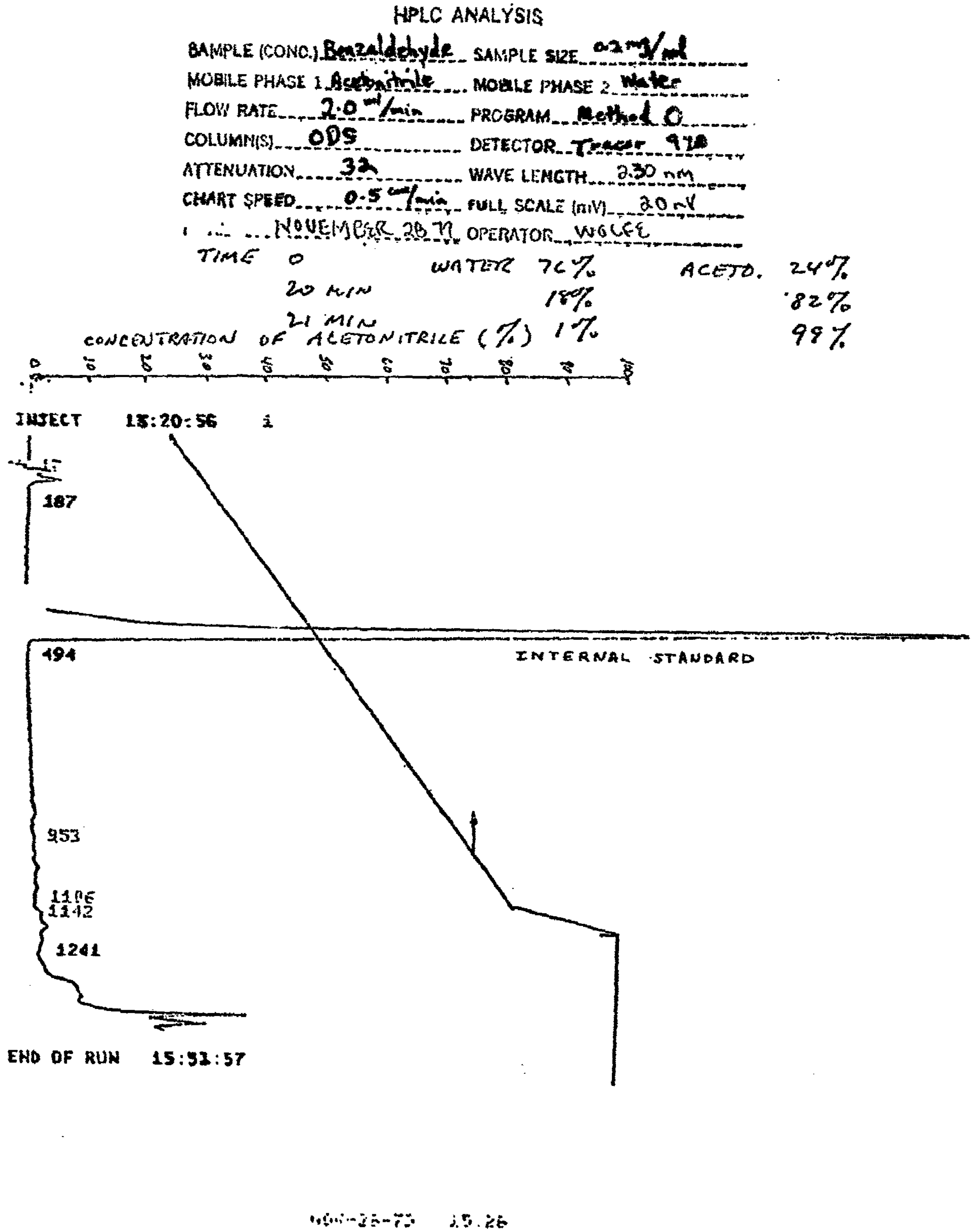


Figure 43. HPLC Analysis of Benzaldehyde.

TABLE 35

TENSILE PROPERTIES OF HyE2034D COMPOSITE LAMINATES

Composite Material Properties

Material System - HyE 2034D	Prepreg by - Fiberite
Fiber - VSC-32 - Matrix - 934	HMG/Epoxy
Maximum Rated Temperature - 350°F(177°C)	Laminate Sp. Gr. - 1.81
Resin Content - 21.[illegible]% by wt.	Nominal Ply Thickness - 0.0049 inch
Fiber Content - 65.[illegible]% by vol.	No. of panels from which specimens were tested in this table - 6
Void Content - 0	
Thickness of each type specimen: 0° - 6 ply ; 90° - 15 ply	

TENSION: 0°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{tu} [ksi](MPa)	[122.3] (843)	[106.5] (734)	[133.5] (920)	[135.0] (930)
Stnd.Dev. [ksi](MPa)	[29.2] (201)	[33.8] (233)	[26.7] (184)	[26.1] (180)
Range [ksi](MPa)	[90.7-157.0] (625-1082)	[72.1-151.6] (497-1044)	[96.5-167.3] (665-1153)	[130.0-165.0] (896-1137)
No. of Specimens	5	5	5	5
F_x^{tpl} [ksi](MPa)	[122.3] (843)	[106.5] (734)	[133.5] (920)	[135.0] (930)
Stnd.Dev. [ksi](MPa)	[29.2] (201)	[33.8] (233)	[26.7] (184)	[26.1] (180)
No. of Specimens	5	5	5	5
E_x^t [Msi](GPa)	[55.9] (385)	[44.5] (307)	[48.4] (333)	[48.7] (336)
Stnd.Dev. [Msi](GPa)	[10.6] (73)	[3.1] (21)	[3.2] (22)	[3.8] (26)
No. of Specimens	5	5	5	5
ϵ_x^{tu} [μin/in](μcm/cm)	2150	2080	2780	2660
Stnd.Dev.	550	570	250	520
No. of Specimens	4	5	5	5
ν_{xy}^t	0.30	0.22	0.32	0.30
Stnd. Dev.	0.06	0.17	0.09	0.06
No. of Specimens	3	5	5	5
Test Method Reference	Straight-sided tension ASTM D3039			

TENSION: 90°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_y^{tu} [ksi](MPa)	[2.19] (15.1)	[2.07] (14.3)	[1.73] (11.9)	[1.47] (10.1)
Stnd.Dev. [ksi](MPa)	[0.52] (3.6)	[0.24] (1.7)	[0.38] (2.6)	[0.32] (2.2)
Range	[1.56-2.68] (10.7-18.5)	[1.81-2.34] (12.5-16.1)	[1.24-2.21] (8.5-15.2)	[0.91-1.92] (6.3-13.2)
No. of Specimens	5	5	5	9
F_y^{tpl} [ksi](MPa)	[2.19] (15.1)	[2.07] (14.3)	[1.73] (11.9)	[0.97] (6.7)
Stnd.Dev. [ksi](MPa)	[0.52] (3.6)	[0.24] (1.7)	[0.38] (2.6)	[0.27] (1.9)
No. of Specimens	5	5	5	10
E_y^t [Msi](GPa)	[0.92] (6.3)	[0.87] (6.0)	[0.79] (5.4)	[0.98] (6.8)
Stnd.Dev. [Msi](GPa)	[0.10] (0.7)	[0.03] (0.2)	[0.01] (0.07)	[0.18] (1.2)
No. of Specimens	5	5	5	10
ϵ_y^{tu} [μin/in](μcm/cm)	2260	2360	2220	1844
Stnd. Dev.	490	297	507	436
No. of Specimens	5	5	5	9
ν_{yx}^t	0.005[1]	0.004[1]	0.005[1]	0.006[1]
Stnd. Dev.	---	---	---	---
No. of Specimens	---	---	---	---
Test Method Reference	Straight-sided tension ASTM D3039			

[1]Computed using elastic moduli and longitudinal Poisson's ratio.

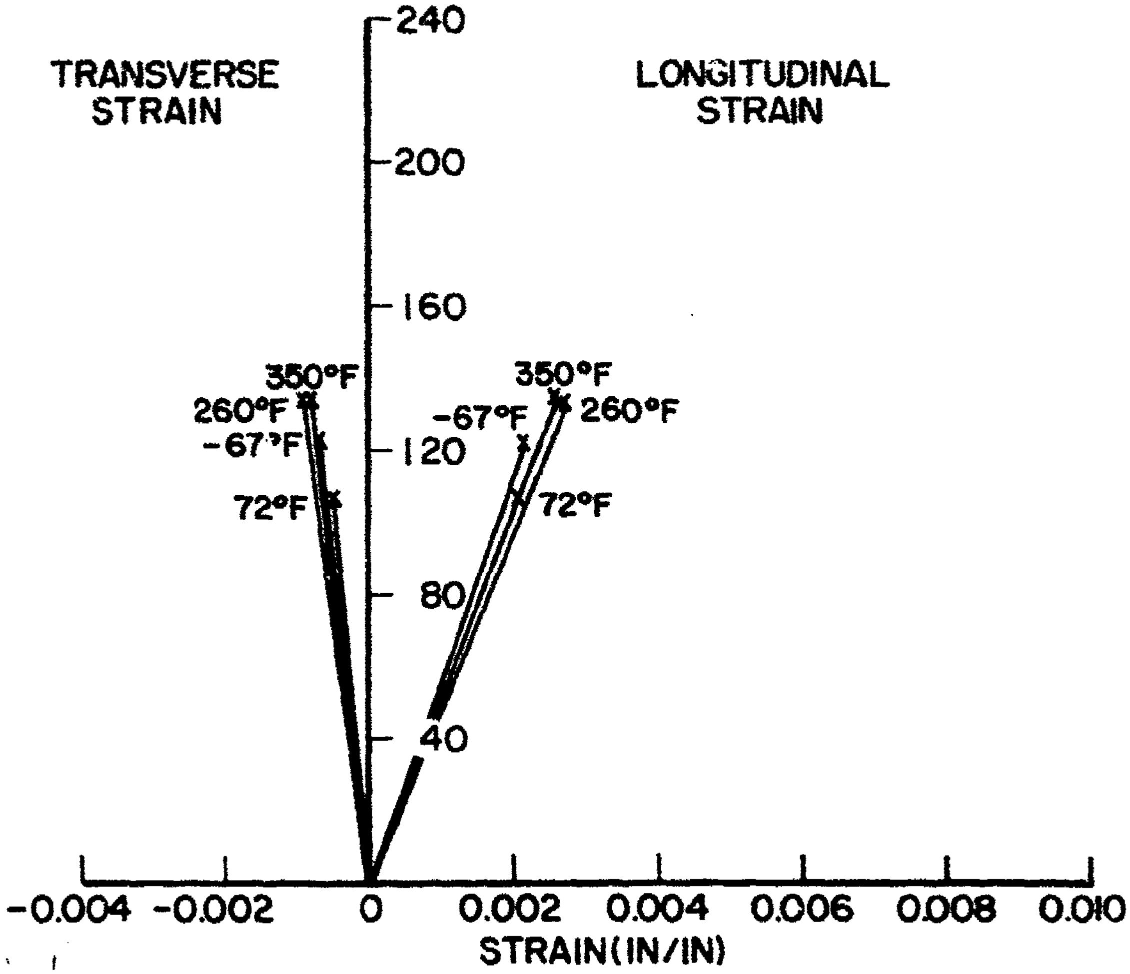


Figure 44. Tensile Stress-Strain Curves for Unidirectional HyE 2034D Composite Laminates: 0° Fiber Orientation.

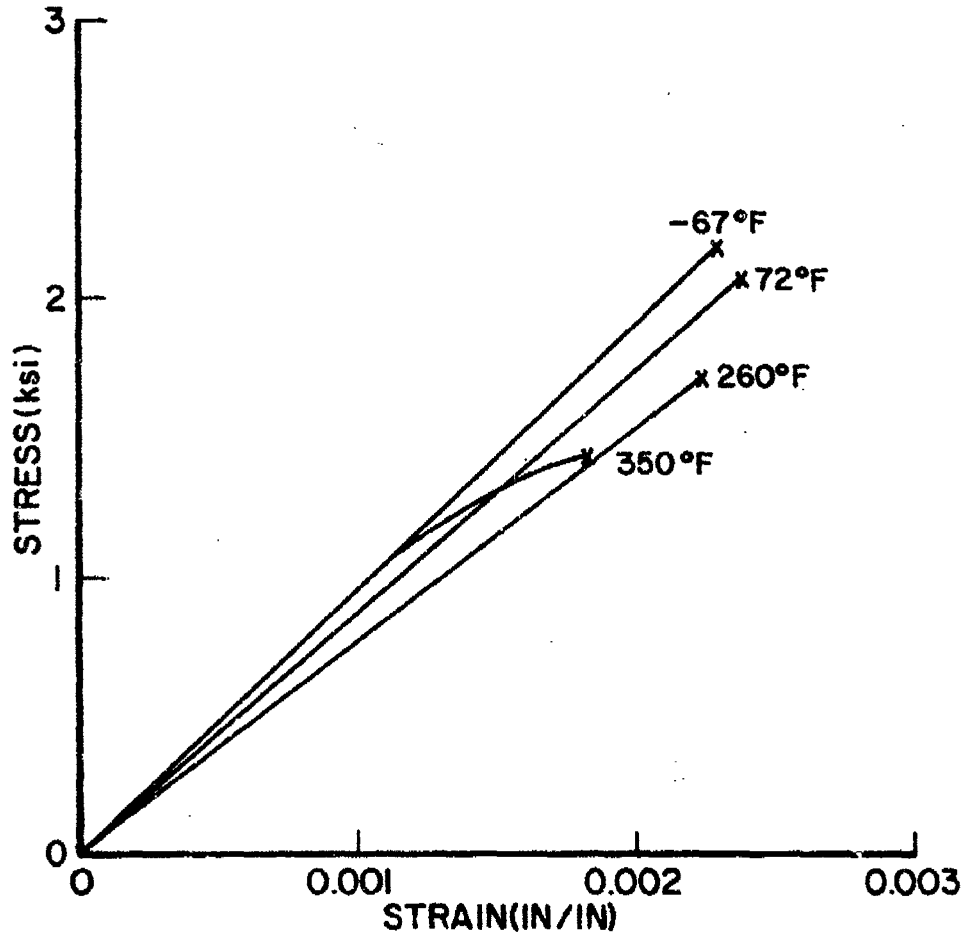


Figure 45. Tensile Stress-Strain Curves for Unidirectional HyE 2034D Composite Laminates: 90° Fiber Orientation.

TABLE 36

TENSILE PROPERTIES OF HyE2034D COMPOSITE LAMINATES

Composite Material Properties				
Material System - HyE 2034D Fiber - VSC-32 Matrix - 934 Maximum Rated Temperature - 350°F(177°C) Resin Content - 24.8% by wt. Fiber Content - 67.9% by vol. Void Content - ~0		Prepreg by - Fiberite Laminate Sp. Gr. - 1.80 Nominal Ply Thickness - 0.0051 inch No. of panels from which specimens were tested in this table - 10 Thickness of specimen - 8 ply		HMG/Epoxy

TENSION: ±45°	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{tu} [ksi] (MPa)	[11.86] (81.7)	[10.85] (74.8)	[9.39] (64.7)	[8.76] (60.4)
Stnd.Dev. [ksi] (MPa)	[0.46] (3.2)	[0.35] (2.4)	[0.29] (2.0)	[0.34] (2.3)
Range [ksi] (MPa)	[11.34-12.45] (78.1-85.8)	[10.29-11.18] (70.9-77.0)	[8.95-9.75] (61.7-67.2)	[8.42-9.13] (58.0-62.9)
No. of Specimens	5	5	5	5
F_x^{tpl} [ksi] (MPa)	[4.26] (29.4)	[4.58] (31.6)	[3.50] (24.1)	[2.95] (20.3)
Stnd.Dev. [ksi] (MPa)	[0.38] (2.6)	[0.34] (2.3)	[1.03] (7.1)	[0.39] (2.7)
No. of Specimens	5	5	5	5
E_x^t [Msi] (GPa)	[3.50] (24.1)	[2.74] (18.9)	[2.23] (15.4)	[2.41] (16.6)
Stnd.Dev. [Msi] (GPa)	[0.11] (0.8)	[0.07] (0.5)	[0.51] (3.5)	[0.30] (2.1)
No. of Specimens	5	5	5	5
ϵ_x^{tu} [μin/in] (μcm/cm)	4500	5780	6390	7680
Stnd. Dev.	480	640	1480	950
No. of Specimens	5	5	5	5
ν_{xy}^t	0.74	0.87	0.85	0.96
Stnd. Dev.	0.04	0.12	0.11	0.14
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3039			

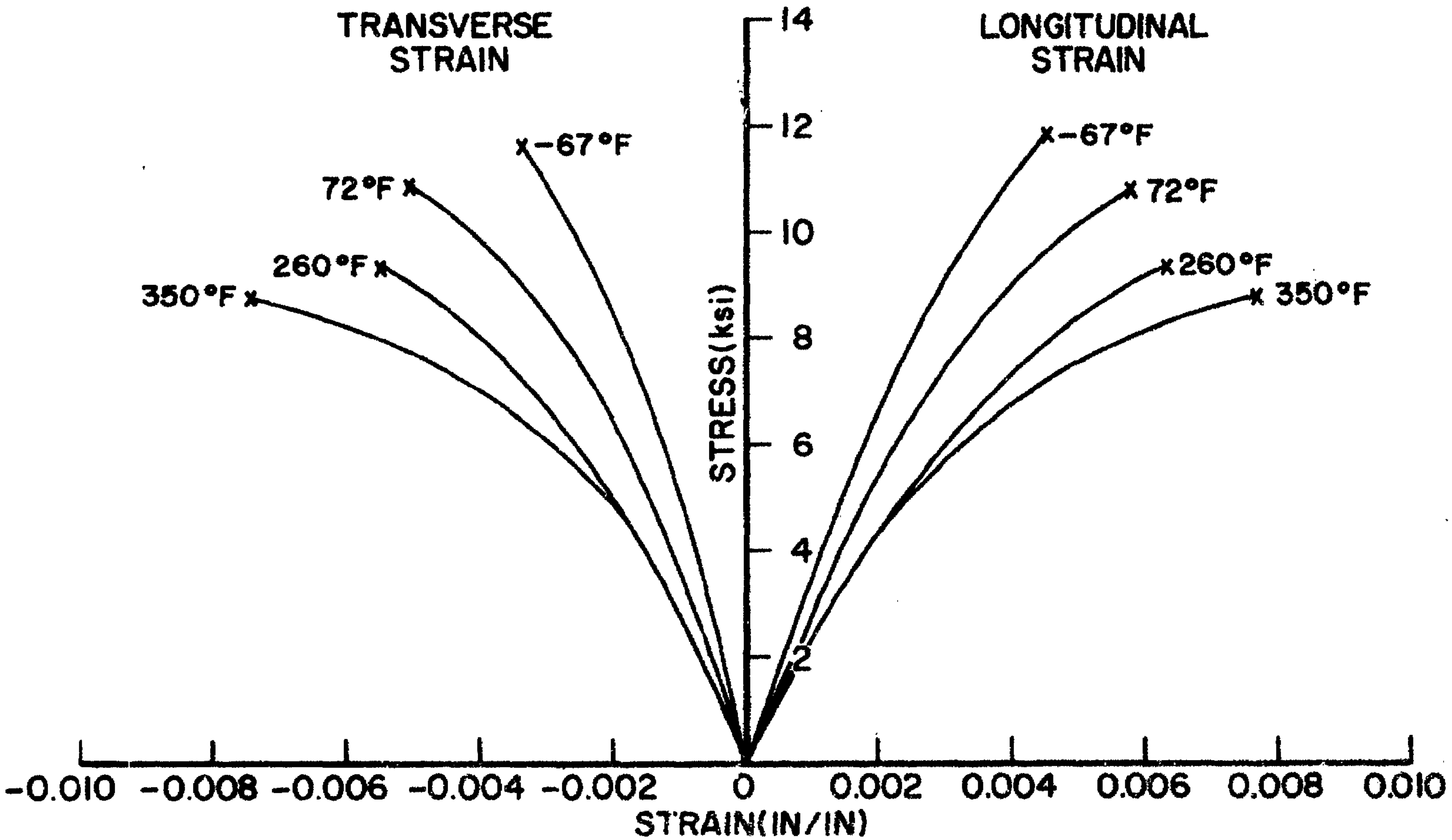


Figure 46. Tensile Stress-Strain Curves for Bidirectional HyE 2034D Composite Laminates: ±45° Fiber Orientation.

TABLE 37

TENSILE PROPERTIES OF HyE2034D COMPOSITE LAMINATES

Composite Material Properties

Material System - HyE 2034D	Prepreg by - Fiberite
Fiber - VSC-32 Matrix - 934	HMG/Epoxy
Maximum Rated Temperature - 350°F(177°C)	Laminate Sp. Gr. - 1.81
Resin Content - 24.3% by wt.	Nominal Ply Thickness - 0.0049 inch
Fiber Content - 67.7% by vol.	No. of panels from which specimens were tested in this table - 8
Void Content - ≐ 0	
Thickness of each type specimen: 20 ply	

TENSION: (0, +45, -45, 0, 0, -45, +45, 0, 90, 0)$_s$

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{tu} [ksi](MPa)		[75.8] (522)	[83.8] (577)	[82.8] (570)
Stnd.Dev.[ksi](MPa)		[8.1] (56)	[3.3] (23)	[8.7] (60)
Range [ksi](MPa)		[65.7-83.0] (453-572)	[80.4-88.2] (554-608)	[71.4-90.8] (492-626)
No. of Specimens		5	5	5
F_x^{tpl} [ksi](MPa)		[67.1] (462)	[83.8] (577)	[82.8] (570)
Stnd.Dev.[ksi](MPa)		[7.9] (54)	[3.3] (23)	[8.7] (60)
No. of Specimens		5	5	5
E_x^t [Msi](GPa)		[28.4] (196)	[26.7] (184)	[28.0] (193)
Stnd.Dev.[Msi](GPa)		[1.7] (12)	[1.1] (8)	[3.9] (27)
No. of Specimens		5	5	5
ϵ_x^{tu} [μin/in](μcm/cm)		2725	3100	2720
Stnd.Dev.		320	360	190
No. of Specimens		5	3	5
ν_{xy}^t		0.415	0.400	0.382
Stnd. Dev.		—	0.044	0.071
No. of Specimens		1	5	5
Test Method Reference	ASTM D3039			

TENSION: (0, +45, -45, 0, 0, -45, +45, 0, 90, 0)$_s$ with 0.1935 inch (0.491 cm) hole

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_y^{tu} [ksi](MPa)		[64.7] (446)		
Stnd.Dev.[ksi](MPa)		[2.3] (16)		
Range		[61.2-67.1] (422-462)		
No. of Specimens		5		
F_y^{tpl} [ksi](MPa)				
Stnd.Dev.[ksi](MPa)				
No. of Specimens				
E_y^t [Msi] (GPa)				
Stnd.Dev.[Msi] (GPa)				
No. of Specimens				
ϵ_y^{tu} [μin/in](μcm/cm)				
Stnd. Dev.				
No. of Specimens				
ν_{yx}^t				
Stnd. Dev.				
No. of Specimens				
Test Method Reference				

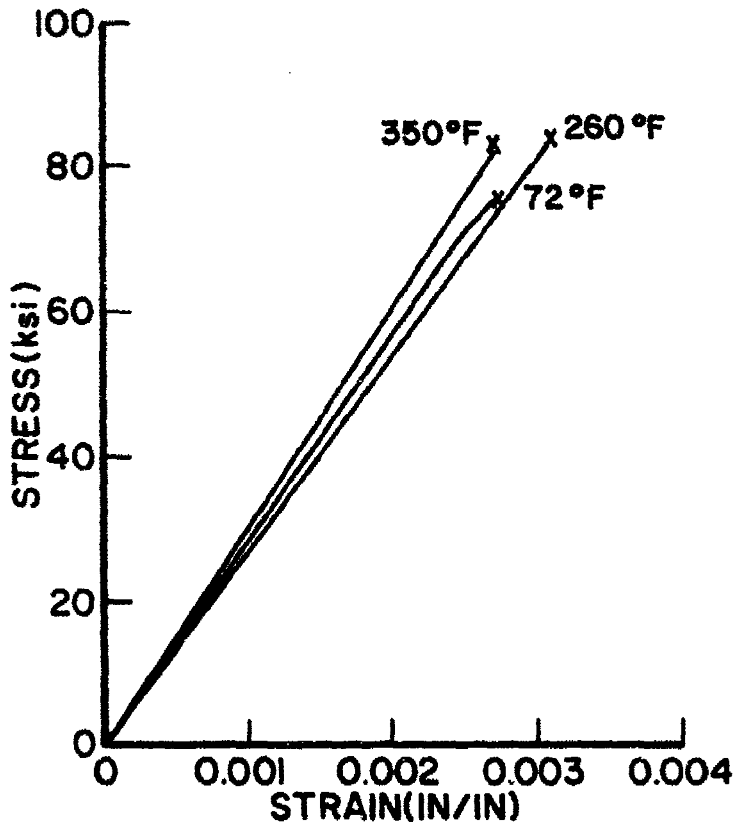


Figure 47. Tensile Stress-Strain Curves for Multidirectional HyE 2034D Composite Laminates: $(0,45,-45,0,0,-45,45,0,90,0)_s$ Fiber Orientation.

TABLE 38

COMPRESSIVE PROPERTIES OF HyE2034D COMPOSITE LAMINATES

Composite Material Properties

Material System - HyE 2034D
Fiber - VSC-32 Matrix - 934
Maximum Rated Temperature - 350°F(177°C)
Resin Content - 23.7% by wt.
Fiber Content - 69.1% by vol.
Void Content - ~0
Thickness of each type specimen: 0° - 20 ply ; 90° - 20 ply

Prepreg by - Fiberite | HMG/Epoxy
Laminate Sp. Gr. - 1.81
Nominal Ply Thickness - 0.0048 inch
No. of panels from which specimens were tested in this table - 2

COMPRESSION: 0°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{cu} [ksi](MPa)	[53.81] (371)	[48.51] (334)	[42.00] (289)	[42.03] (290)
Stnd.Dev. [ksi](MPa)	[5.69] (39)	[5.71] (39)	[6.63] (46)	[6.95] (48)
Range [ksi](MPa)	[45.87 - 61.24] (316 - 422)	[41.91 - 55.56] (289 - 383)	[31.16 - 48.00] (215 - 331)	[32.21 - 48.53] (222 - 334)
No. of Specimens	5	5	5	4
F_x^{cpl} [ksi](MPa)	[35.66] (246)	[25.77] (178)	[22.75] (157)	[25.27] (174)
Stnd.Dev. [ksi](MPa)	[6.28] (43)	[12.81] (88)	[9.73] (67)	[8.08] (56)
No. of Specimens	5	5	5	4
E_x^c [Msi](GPa)	[37.03] (255)	[45.90] (316)	[44.29] (305)	[43.42] (299)
Stnd.Dev. [Msi](GPa)	[3.70] (25)	[10.67] (74)	[7.77] (54)	[8.42] (58)
No. of Specimens	5	5	5	5
ε_x^{cu} [μin/in](μcm/cm)	1740	1300	1320	1180
Stnd. Dev.	230	290	240	50
No. of Specimens	5	5	5	4
Test Method Reference	ASTM D3410			

COMPRESSION: 90°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_y^{cu} [ksi](MPa)	[19.08] (131)	[17.55] (121)	[13.05] (90)	[11.49] (79)
Stnd.Dev. [ksi](MPa)	[2.67] (18)	[3.30] (23)	[1.13] (8)	[1.58] (11)
Range	[15.12-20.88] (104 - 144)	[15.07-22.38] (104 - 154)	[12.08-14.69] (83 - 101)	[8.75-12.50] (60 - 86)
No. of Specimens	4	4	5	5
F_y^{cpl} [ksi](MPa)	[6.76] (47)	[3.17] (22)	[6.58] (45)	[2.19] (15)
Stnd.Dev. [ksi](MPa)	[6.03] (41)	[2.44] (17)	[5.24] (36)	[1.39] (10)
No. of Specimens	4	4	5	5
E_y^c [Msi](GPa)	[1.76] (12)	[1.62] (11)	[1.14] (8)	[0.92] (6)
Stnd.Dev. [Msi](GPa)	[0.78] (5)	[0.24] (2)	[0.26] (2)	[0.12] (1)
No. of Specimens	4	4	5	5
ε_y^{cu} [μin/in](μcm/cm)	19,980	35,950	13,880	25,040
Stnd. Dev.	1,540	12,220	3,970	5,250
No. of Specimens	4	4	5	5
Test Method Reference	ASTM D3410			

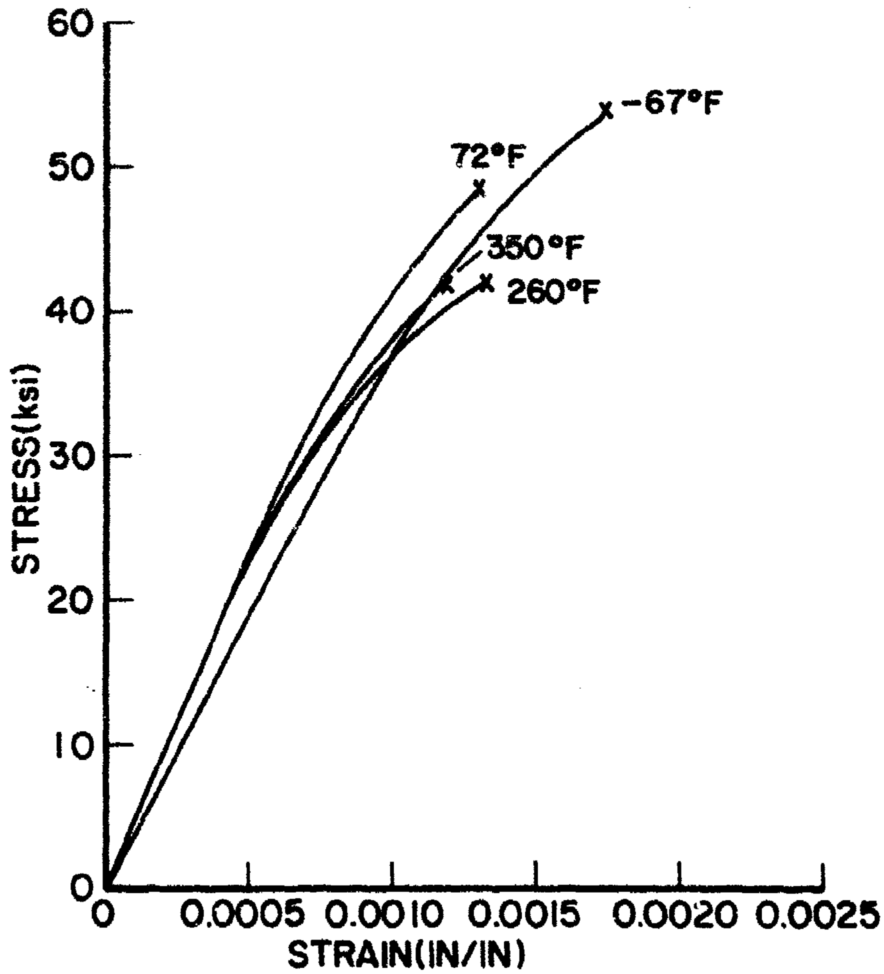


Figure 48. Compressive Stress-Strain Curves for Unidirectional HyE 2034D Composite Laminates: 0° Fiber Orientation.

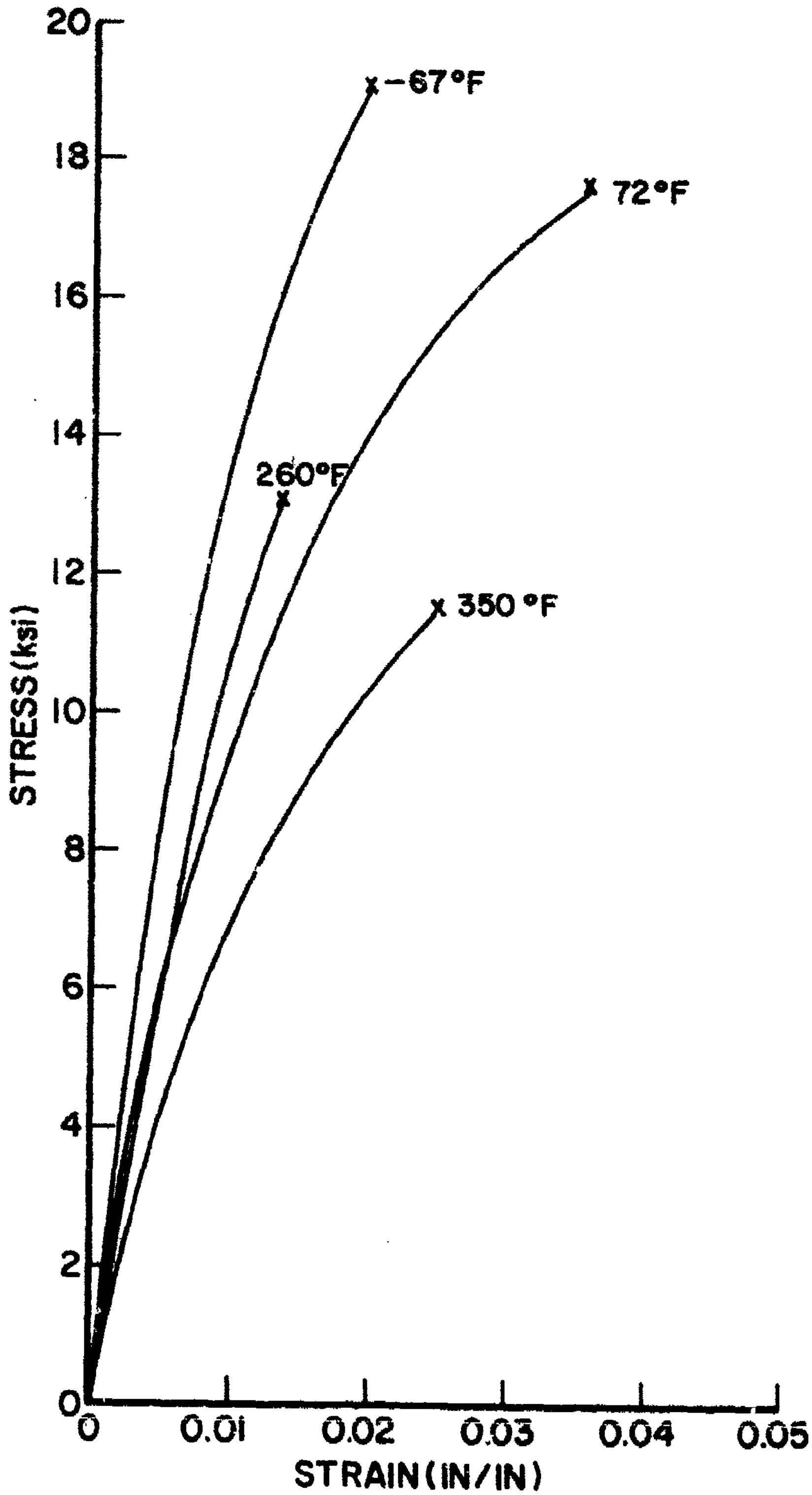


Figure 49. Compressive Stress-Strain Curves for Unidirectional HyE 2034D Composite Laminates: 90° Fiber Orientation.

TABLE 39

FLEXURAL PROPERTIES OF HyE2034D COMPOSITE LAMINATES

Composite Material Properties

Material System - HyE 2034D Fiber - VSC-32 Matrix - 934 Maximum Rated Temperature - 350°F(177°C) Resin Content - 23.4% by wt. Fiber Content - 69.8% by vol. Void Content - ~0 Thickness of each type specimen: 0° - 14 ply ; 90° - 14 ply	Prepreg by - Fiberite — HMG/Epoxy Laminate Sp. Gr. - 1.82 Nominal Ply Thickness - 0.0049 inch No. of panels from which specimens were tested in this table - 1

FLEXURE: 0°

	-67°F(-55°C)	72°F(22°C)	260°F (127°C)	350°F (177°C)
F_x^{fu} [ksi](MPa)	[86.9] (599)	[90.2] (621)	[66.6] (459)	[66.9] (461)
Stnd.Dev. [ksi](MPa)	[17.1] (118)	[1.9] (13.1)	[2.5] (17.2)	[3.0] (21.0)
Range [ksi](MPa)	[62.2-107.1] (429-738)	[87.4-91.9] (602-633)	[62.8-69.0] (433-475)	[63.3-70.0] (436-482)
No. of Specimens	5	5	5	5
E_x^f [Msi](GPa)	[35.3] (243)	[41.6] (287)	[37.5] (258)	[40.3] (278)
Stnd.Dev. [Msi](GPa)	[10.9] (75)	[1.6] (11.0)	[9.5] (65.5)	[3.0] (21.0)
No. of Specimens	5	5	5	5
Test Method Reference	4 pt. flexure Design Guide, Jan. 1971 } Corresponds to ASTM D790 except for loading points and loading speed.			

FLEXURE: 90°

	-67°F(-55°C)	72°F(22°C)	260°F (127°C)	350°F (177°C)
F_y^{fu} [ksi](MPa)	[5.57] (38.4)	[5.30] (36.5)	[3.67] (25.3)	[2.80] (19.3)
Stnd.Dev. [ksi](MPa)	[0.19] (1.3)	[0.37] (2.54)	[0.17] (1.17)	[0.27] (1.5)
Range [ksi](MPa)	[5.28-5.75] (36.4-39.6)	[4.80-5.72] (33.1-39.4)	[3.38-3.78] (23.3-26.0)	[2.51-3.20] (17.3-22.0)
No. of Specimens	5	5	5	5
E_y^f [Msi](GPa)	[1.07] (7.4)	[1.09] (7.5)	[0.90] (6.2)	[0.77] (5.3)
Stnd.Dev. [Msi](GPa)	[0.04] (0.3)	[0.06] (0.4)	[0.04] (0.3)	[0.02] (1.5)
No. of Specimens	5	5	5	5
Test Method Reference	4 pt. flexure Design Guide, Jan. 1971 } Corresponds to ASTM D790 except for loading points and loading speed.			

TABLE 40

SHEAR PROPERTIES OF HyE2034D COMPOSITE LAMINATES

Composite Material Properties

Material System - HyE 2034D	Prepreg by - Fiberite HMG/Epoxy
Fiber - VSC-32 Matrix - 934	Laminate Sp. Gr. - 1.81
Maximum Rated Temperature - 350°F(177°C)	Nominal Ply Thickness - 0.0048 inch
Resin Content - 24.9% by wt.	No. of panels from which specimens were tested in this table - 11
Fiber Content - 67.9% by vol.	
Void Content - ~ 0	
Thickness of each type specimen - Inplane - 8 ply ; Interlaminar - 15 ply	

INPLANE SHEAR

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F^{su}_{xy} [ksi](MPa)	[5.93] (40.9)	[5.43] (37.4)	[4.69] (32.3)	[4.38] (30.2)
Stnd.Dev. [ksi](MPa)	[0.23] (1.6)	[0.17] (1.2)	[0.14] (1.0)	[0.17] (1.2)
Range [ksi](MPa)	[5.67-6.22] (39.1-42.9)	[5.14-5.59] (35.4-38.5)	[4.48-4.88] (30.9-33.6)	[4.21-4.50] (29.0-31.4)
No. of Specimens	5	5	5	5
G^{s}_{xy} [Msi](GPa)	[1.07] (7.4)	[0.73] (5.0)	[0.66] (4.5)	[0.61] (4.2)
Stnd.Dev. [Msi](GPa)	[0.14] (1.0)	[0.06] (0.4)	[0.02] (0.1)	[0.04] (0.3)
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D358			

INTERLAMINAR SHEAR

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F^{isu} [ksi](MPa)	[8.09] (55.7)	[7.18] (49.5)	[6.48] (44.6)	[5.83] (40.2)
Stnd.Dev. [ksi](MPa)	[0.59] (4.1)	[0.46] (3.2)	[0.48] (3.3)	[0.26] (1.8)
Range	[7.51-9.06] (51.7-62.4)	[6.45-7.85] (44.4-54.1)	[6.04-7.12] (41.6-49.1)	[5.48-6.17] (37.7-42.5)
No. of Specimens	5	10	5	5
Test Method Reference	Short Beam Shear 4:1 Advanced Composite Design Guide - Jan., 1971			

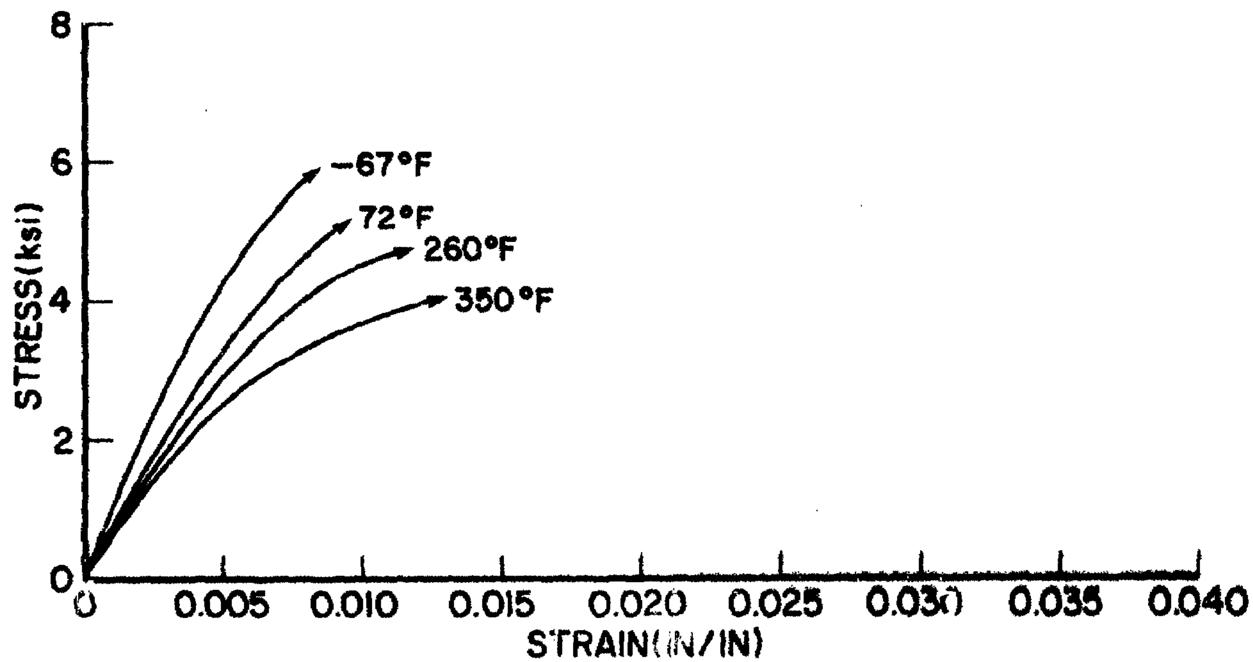


Figure 50. Inplane Shear Stress-Strain Curves for HyE 2034D Composite Laminates.

TABLE 41

TENSILE, COMPRESSIVE, AND SHEAR PROPERTIES OF HyE 2034D COMPOSITE LAMINATES AFTER HUMIDITY AGING

Composite Material Properties

Material System - HyE 2034D	Prepreg by - Fiberite
Fiber - VSC-32 Matrix - 934	Laminate Sp. Gr. - 1.80
Maximum Rated Temperature - 350°F	Nominal Ply Thickness - 0.0048 inch
Resin Content - 24.3% by wt.	No. of panels from which specimens were tested in this table - 9
Fiber Content - 68.5% by vol.	Aging Conditions - 160°F & 95-100% R.H.
Void Content - ~0	HMG/Epoxy
Thickness of each type specimen:	Tension - 15 ply; Compr. - 20 ply; Shear - 15 ply

TENSION: 90°

	72°F (22°C)	260°F (127°C)	72°F (22°C)	260°F (127°C)
Exposure Time (hrs)	217	217	982	982
Wt. Gain (% of orig. dry wt.)	0.79	0.79	1.18[1]	1.19[1]
Stnd. Dev. (%)	0.01	0.01	0.03	0.05
No. of Specimens	5	5	5	5
F_y^{tu} [ksi] (MPa)	[2.53] (17.4)	[1.72] (11.9)	[2.05] (14.1)	[1.04] (7.2)
Stnd. Dev. [ksi] (MPa)	[0.34] (2.3)	[0.17] (1.2)	[0.29] (2.0)	[0.13] (0.9)
Range [ksi] (MPa)	[2.13-2.85] (14.7-19.6)	[1.44-1.89] (9.9-13.0)	[1.65-2.38] (11.4-16.4)	[0.88-1.21] (6.1-8.3)
No. of Specimens	5	5	5	5
F_y^{tpl} [ksi] (MPa)	[0.98] (6.7)	[0.80] (5.5)	[1.49] (10.3)	[0.89] (6.1)
Stnd. Dev. [ksi] (MPa)	[0.20] (1.4)	[0.16] (1.1)	[0.29] (2.0)	[0.09] (0.6)
No. of Specimens	5	5	5	5
E_y^t [Msi] (GPa)	[0.95] (6.5)	[0.71] (4.9)	[1.00] (6.9)	[0.52] (3.6)
Stnd. Dev. [Msi] (GPa)	[0.03] (0.2)	[0.04] (0.3)	[0.05] (0.3)	[0.09] (0.6)
No. of Specimens	5	5	5	5
ϵ_y^{tu} [μin/in] (μcm/cm)	2720	2660	2100	2200
Stnd. Dev.	300	280	260	280
No. of Specimens	5	5	5	5
Test Method Reference	Straight-sided tension ASTM D3039			

COMPRESSION: 90°

	72°F (22°C)	260°F (127°C)	72°F (22°C)	260°F (127°C)
Exposure Time (hrs)	145	145	1706	2183
Wt. Gain (% of orig. dry wt.)	0.74	0.76	1.33[1]	1.39[1]
Stnd. Dev. (%)	0.03	0.03	0.03	0.12
No. of Specimens	5	5	5	5
F_y^{cu} [ksi] (MPa)	[14.12] (97.3)	[13.39] (92.3)	[15.19] (104.7)	[16.04] (111)
Stnd. Dev. [ksi] (MPa)	[2.56] (17.6)	[1.58] (10.9)	[2.38] (16.4)	[2.88] (20)
Range	[12.00-17.59] (82.7-121.2)	[11.26-15.62] (77.6-107.6)	[13.59-19.34] (93.4-133.3)	[13.33-19.63] (92 - 135)
No. of Specimens	4	5	5	4
F_y^{cpl} [ksi] (MPa)	[2.83] (19.5)	[2.49] (17.2)	[5.58] (38.4)	[2.82] (19.4)
Stnd. Dev. [ksi] (MPa)	[0.75] (5.2)	[0.27] (1.9)	[1.35] (9.3)	[0.86] (5.9)
No. of Specimens	4	4	5	4
E_y^c [Msi] (GPa)	[1.92] (13.2)	[1.38] (9.5)	[1.05] (7.2)	[1.07] (7.4)
Stnd. Dev. [Msi] (GPa)	[0.79] (5.4)	[0.38] (2.6)	[0.13] (0.9)	[0.17] (1.2)
No. of Specimens	4	5	5	5
ϵ_y^{cu} [μin/in] (μcm/cm)	20,480	18,490	15,180	19,280
Stnd. Dev.	7,360	4,600	2,620	5,140
No. of Specimens	4	5	5	4
Test Method Reference	ASTM D3410			

INTERLAMINAR SHEAR

	72°F (22°C)	260°F (127°C)	72°F (22°C)	260°F (127°C)
Exposure Time (hrs)	162	167	862	862
Wt. Gain (% of orig. dry wt.)	0.72	0.71	1.39[1]	1.37[1]
Stnd. Dev. (%)	0.07	0.15	0.17	0.17
No. of Specimens	10	5	10	5
F^{isu} [ksi] (MPa)	[7.02] (48.4)	[5.56] (38.3)	[7.21] (49.7)	[4.09] (28.2)
Stnd. Dev. [ksi] (MPa)	[0.38] (2.6)	[0.20] (1.4)	[0.35] (2.4)	[0.24] (1.7)
Range [ksi] (MPa)	[6.44-7.64] (44.4-52.6)	[5.33-5.87] (36.7-40.4)	[6.39-7.68] (44.0-52.9)	[3.69-4.32] (25.4-29.8)
No. of Specimens	10	5	10	5
Test Method Reference	ASTM D2344			

NOTE: 1. 100% saturation at aging conditions.

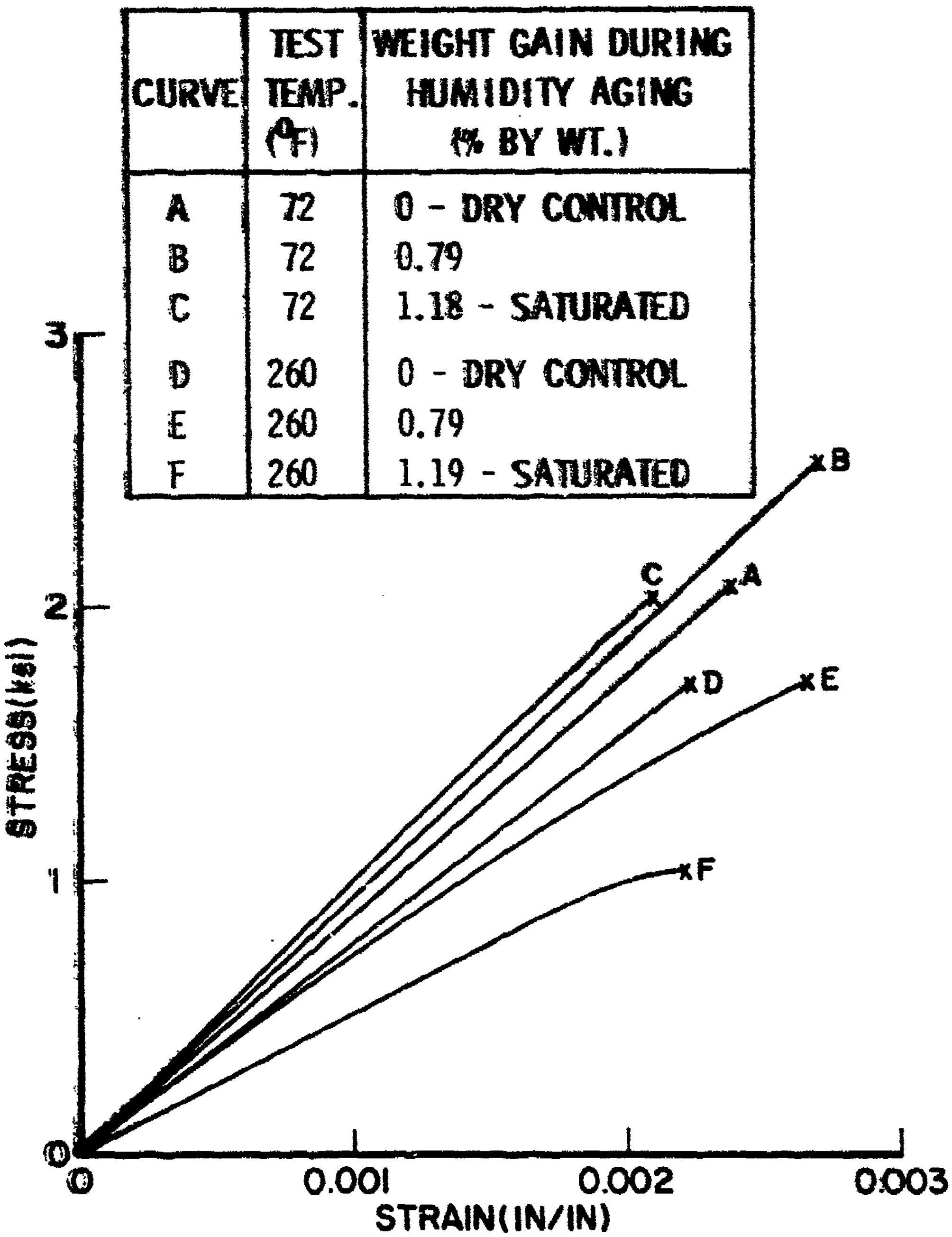


Figure 51 . Tensile Stress-Strain Curves for Unidirectional HyE 2034D Composite Laminates After Humidity Aging at 160°F (71°C) and 100% R.H.: 90° Fiber Orientation.

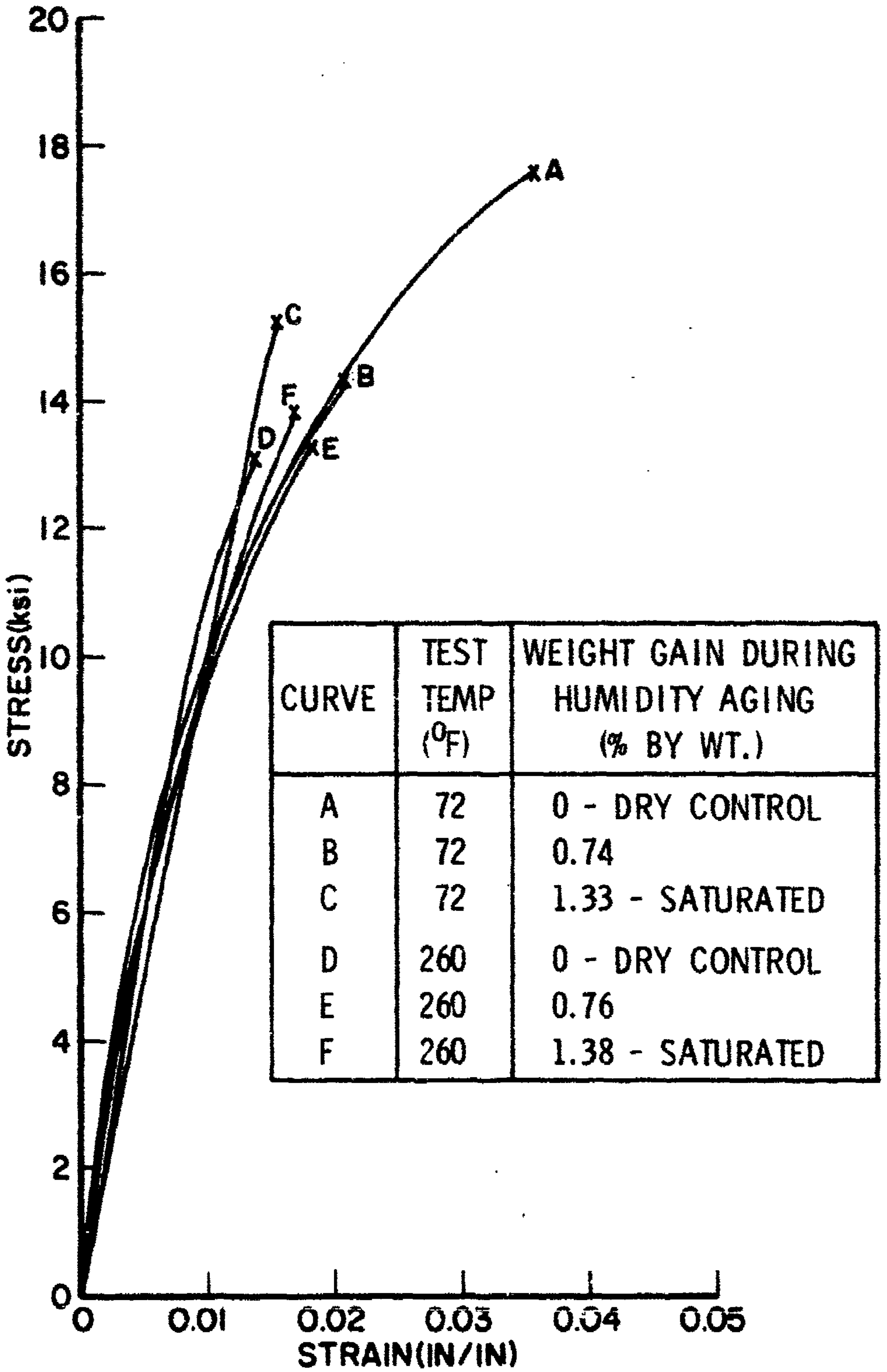


Figure 52. Compressive Stress-Strain Curves for Unidirectional HyE 2034D Composite Laminates After Humidity Aging at 160°F (71°C) and 100% R.H.: 90° Fiber Orientation.

TABLE 42

TENSILE CREEP PROPERTIES OF HyE2034D COMPOSITE LAMINATES

Composite Material Properties	
Material System - HyE 2034D Fiber - VSC-32 Matrix - 934 Maximum Temperature Rating - 350°F(177°C) Resin Content - 23.8% by wt. Fiber Content - 67.9% by vol. Void Content - ≐ 0 Test Method - Straight-sided tension Reference - ASTM D2290 and D3039	Prepreg by - Fiberite — HMG/Epoxy Laminate Sp. Gr. - 1.80 Nominal Ply Thickness - 0.0050 inch No. of panels from which specimens were tested in this table - 18 Thickness of each type specimen: (0/±45/90) - 20 ply ±45° - 8 ply

CREEP

Temperature		$(0,+45,-45,0,0,-45,+45,0,90,0)_s$	±45°
72°F(22°C)	Stress Level [ksi](MPa)	[60.7] (418)	[8.68] (59.8)
	Creep Strain, 500 hr(%)	0.0038 @ 191 hrs[3]	0.1182
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[76.8] (529)	[11.24] (77.4)
	No. of Specimens	3	3
	Stress Level [ksi](MPa)	[53.1] (366)	[7.30] (50.3)
	Creep Strain, 500 hr(%)	0.0071	0.0998
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[75.5] (520)	[11.30] (77.9)
	No. of Specimens	2	3
	Stress Level [ksi](MPa)	[45.5] (313)	[5.43] (37.4)
	Creep Strain, 500 hr(%)	≈0	0.0605
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[77.4] (533)	[11.33] (78.1)
	No. of Specimens	3	3
260°F(127°C)	Stress Level [ksi](MPa)	[60.0] (413)	[6.57] (45.3)
	Creep Strain, 500 hr(%)	0.0036 @ 7 hrs[2]	0.2981 @ 135 hrs[1]
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	---	[11.12] (76.6)
	No. of Specimens	0	2
	Stress Level [ksi](MPa)	[50.0] (345)	[5.63] (38.8)
	Creep Strain, 500 hr(%)	-0.0088[4]	0.2154
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[77.0] (531)	[11.97] (82.5)
	No. of Specimens	3	3
	Stress Level [ksi](MPa)	[40.0] (276)	[4.70] (32.4)
	Creep Strain, 500 hr(%)	-0.0036[4]	0.1419
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[80.4] (554)	[12.77] ([illegible].0)
	No. of Specimens	3	3
350°F(177°C)	Stress Level [ksi](MPa)	[66.2] (456)	[5.25] (36.2)
	Creep Strain, 500 hr(%)	0.0148 @ 342 hrs	0.3661 @ 1 hr.[1]
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[82.6] (569)	---
	No. of Specimens	2	0[2]
	Stress Level [ksi](MPa)	[58.0] (400)	[4.38] (30.2)
	Creep Strain, 500 hr(%)	-0.0034[4]	0.8708 @ 95 hrs.[1]
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[76.7] (528)	[7.33] (50.5)
	No. of Specimens	3	3
	Stress Level [ksi](MPa)	[49.4] (340)	[3.50] (24.1)
	Creep Strain, 500 hr(%)	-0.0020[4]	1.0004 @ 24 hrs.[1]
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[78.6] (542)	[5.51] (38.0)
	No. of Specimens	3	3

[1] Strain exceeded gage limits during test.
[2] Three specimens failed during test.
[3] Gripping tabs debonded from one specimen at 226 hrs. Specimens were retested without strain measurement and ran out to 500 hrs without failure.
[4] Specimen contractions noted at lower stress levels at both 260°F(127°C) and 350°F (177°C). May be due to relaxation of residual curing stresses.

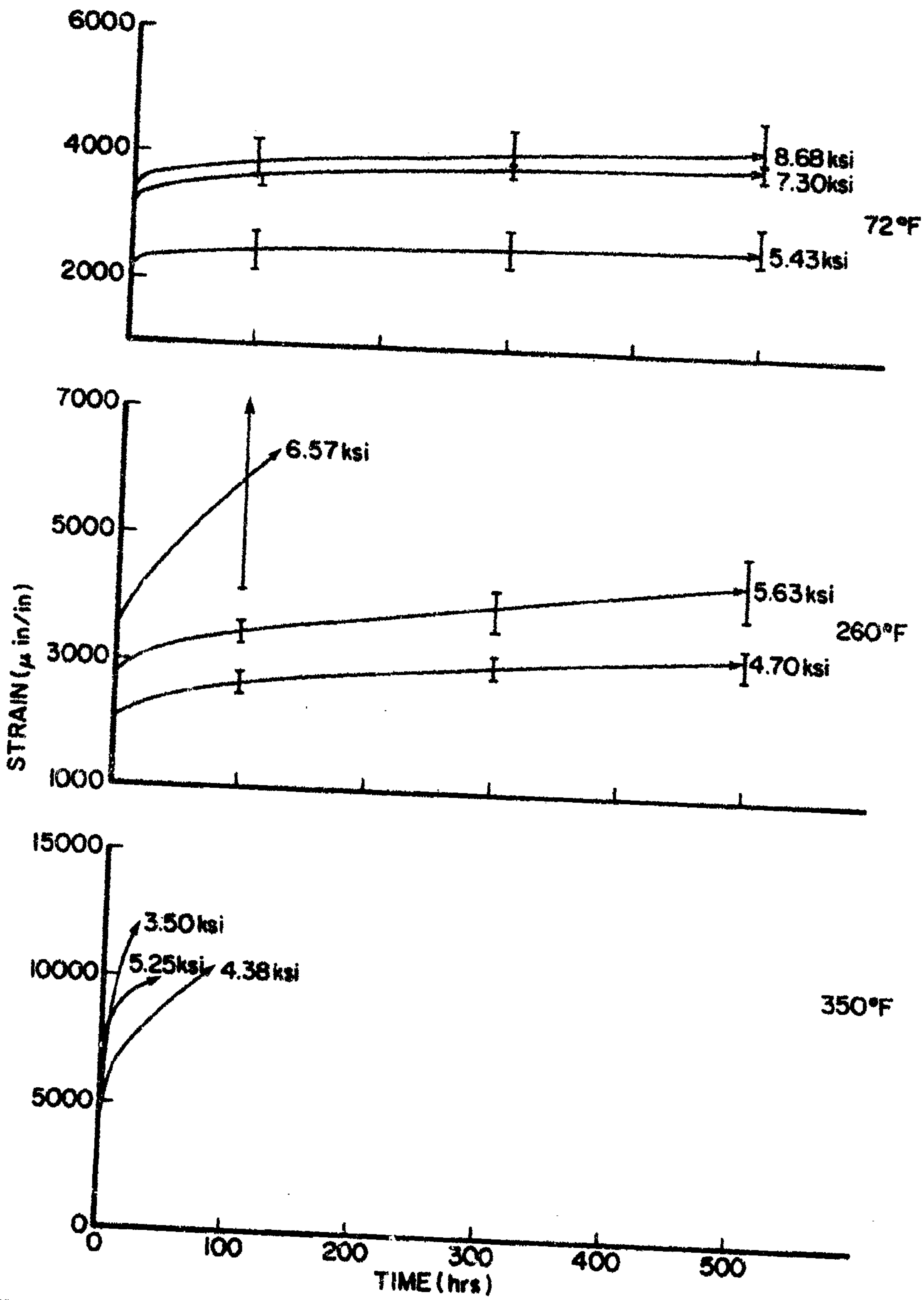


Figure 53. Tensile Creep Behavior of Bidirectional HyE2034D Composite Laminates: ±45° Fiber Orientation.

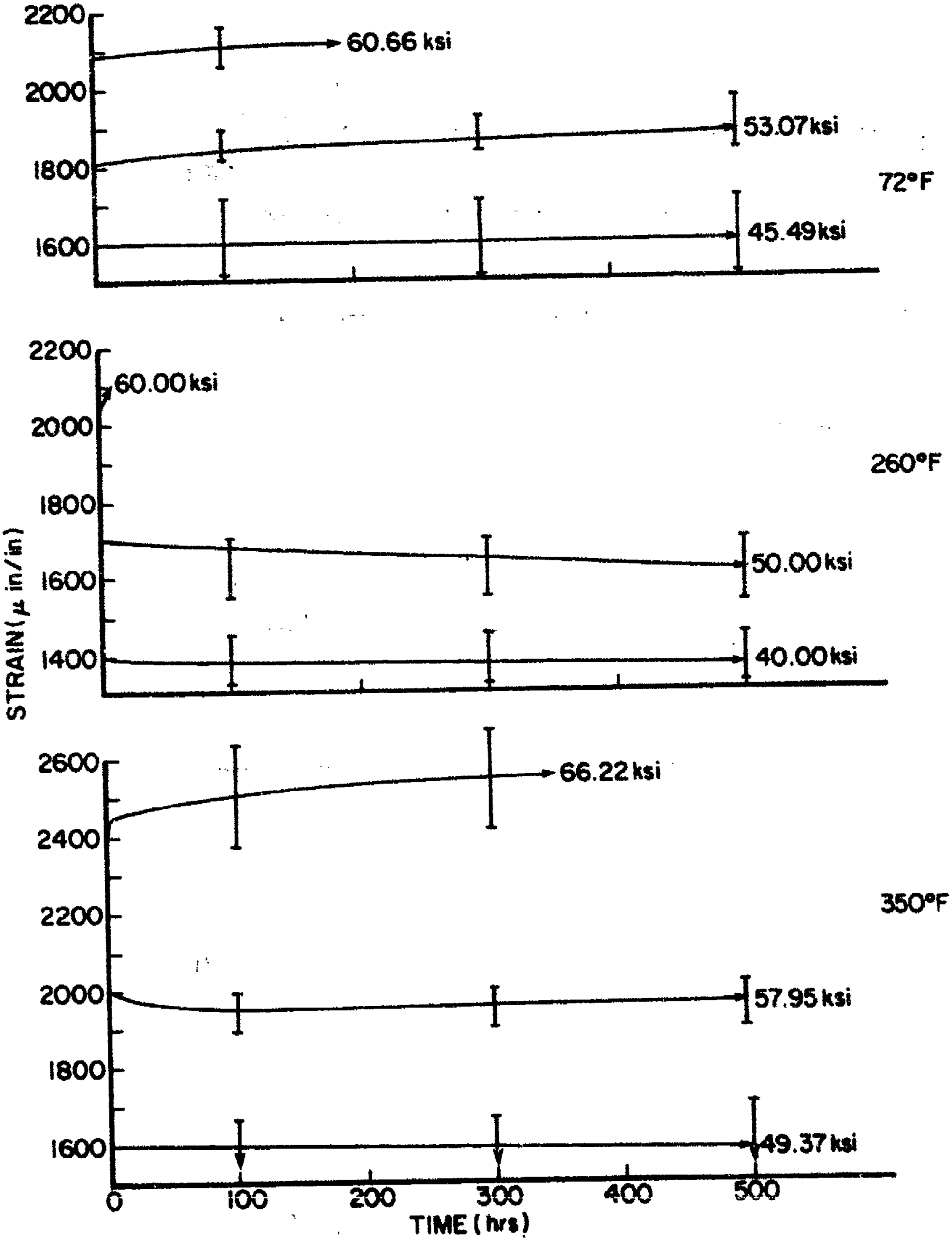


Figure 54. Tensile Creep Behavior of HyE2034D Composite Laminates: $(0,+45,-45,0,0,-45,+45,0,90,0)_s$ Fiber Orientation.

TABLE 43

TENSILE STRESS-RUPTURE PROPERTIES OF HyE2034D COMPOSITE LAMINATES

Composite Material Properties

HMG/Epoxy

Material System - HyE2034D
Fiber - VSC-32 Matrix - 934
Maximum Temperature Rating - 350°F(177°C)
Resin Content - 23.8% by wt.
Fiber Content - 67.9% by vol.
Void Content - ≐ 0

Test Method - Straight-sided tension
Reference - ASTM D2290 and D3039

Prepreg by - Fiberite
Laminate Sp. Gr. - 1.80
Nominal Ply Thickness - 0.0050 inch
No. of panels from which specimens were tested in this table - 18
Thickness of each type specimen:
(0/±45/90) - 20 ply
±45 - 8 ply

STRESS RUPTURE

Temperature	Fiber Orientation	$(0,+45,-45,0,0,-45,+45,0,90,0)_s$	±45°
72°F (22°C)	Stress Level[ksi](MPa)	[60.7] (418)	[8.68] (59.8)
	Time to Failure(hrs)	500+	500+
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[76.8] (529)	[11.24] (77.4)
	No. of Specimens	3	3
	Stress Level[ksi](MPa)	[53.1] (366)	[7.30] (50.3)
	Time to Failure(hrs)	500+	500+
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[75.5] (520)	[11.30] (77.9)
	No. of Specimens	3	3
260°F(127°C)	Stress Level[ksi](MPa)	[60.0] (413)	[6.57] (45.3)
	Time to Failure(hrs)	21	425+[1]
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	---	[11.12] (76.6)
	No. of Specimens	0	2
	Stress Level[ksi](MPa)	[50.0] (345)	[5.63] (38.8)
	Time to Failure(hrs)	500+	500+
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[77.0] (531)	[11.97] (82.5)
	No. of Specimens	3	3
350°F(177°C)	Stress Level[ksi](MPa)	[66.2] (456)	[5.25] (36.2)
	Time to Failure(hrs)	456+[1]	116
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[82.6] (569)	---
	No. of Specimens	2	0
	Stress Level[ksi](MPa)	[58.0] (399)	[4.38] (30.2)
	Time to Failure(hrs)	500+	500+
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[76.7] (528)	[7.33] (50.5)
	No. of Specimens	3	3

[1] Two specimens survived for 500 hrs. without failure.

TABLE 44

TENSION-TENSION FATIGUE PROPERTIES OF HyE2034D COMPOSITE LAMINATES

Composite Material Properties	
Material System - HyE 2034D Fiber - VSC-32 Matrix - 934 Maximum Temperature Rating - 350°F(177°C) Resin Content - 24.8% by wt. Fiber Content - 67.9% by vol. Void Content - ∿ 0 Test Method - Straight-sided tension Reference - ASTM D3039	Prepreg by - Fiberite — HMG/Epoxy Laminate Sp. Gr. - 1.81 Nominal Ply Thickness - 0.0050 inch No. of panels from which specimens were tested in this table - 10 Thickness of each type specimen: ±45° - 8 ply 0/±45/90° - 20 ply

TENSILE FATIGUE, R=0.1 [3]

Temperature	Fiber Orientation	±45°	0/±45/90°[1]	0/±45/90°[1,2]
72°F(22°C)	Max. Stress[ksi](MPa)	[8.68] (59.8)	[75.8] (522)	[61.5] (424)
	Lifetime (cycles)	22,706	34,123	5,148
	No. of Specimens	5	5	3
	Residual Strength[ksi](MPa)	---	---	---
	No. of Specimens	0	0	0
	Max. Stress[ksi](MPa)	[8.14] (56.1)	[73.9] (509)	[60.00] (413)
	Lifetime (cycles)	73,132	11,625	20,000
	No. of Specimens	5	3	3
	Residual Strength[ksi](MPa)	---	---	[67.2] (463)
	No. of Specimens	0	0	1
	Max. Stress[ksi](MPa)	[6.51] (44.9)	[72.0] (496)	[58.3] (401)
	Lifetime (cycles)	7,715,394	96,015	7,602,215+
	No. of Specimens	4	5	3[4]
	Residual Strength[ksi](MPa)	[9.80] (68.0)	[79.2] (546)	[70.4] (485)
	No. of Specimens	3	2	1
260°F(127°C)	Max. Stress[ksi](MPa)	[7.98] (55.0)		
	Lifetime (cycles)	3,870		
	No. of Specimens	5		
	Residual Strength[ksi](MPa)	---		
	No. of Specimens	0		
	Max. Stress[ksi](MPa)	[7.04] (48.5)		
	Lifetime (cycles)	132,425		
	No. of Specimens	5		
	Residual Strength[ksi](MPa)	---		
	No. of Specimens	0		
	Max. Stress[ksi](MPa)	[6.57] (45.3)		
	Lifetime (cycles)	987,695		
	No. of Specimens	4		
	Residual Strength[ksi](MPa)	---		
	No. of Specimens	0		

NOTES:
1. Stacking sequence $(0, +45, -45, 0, 0, -45, +45, 0, 90, 0)_s$
2. These specimens had a 0.1935 inch (0.491 cm) hole in the center of the test section. Stresses calculated using net cross-sectional area.
3. Fatigue lifetimes are log mean values. All residual strengths determined by tensile test at 72°F (22°C).
4. One specimen survived to 10^7 cycles without failure.

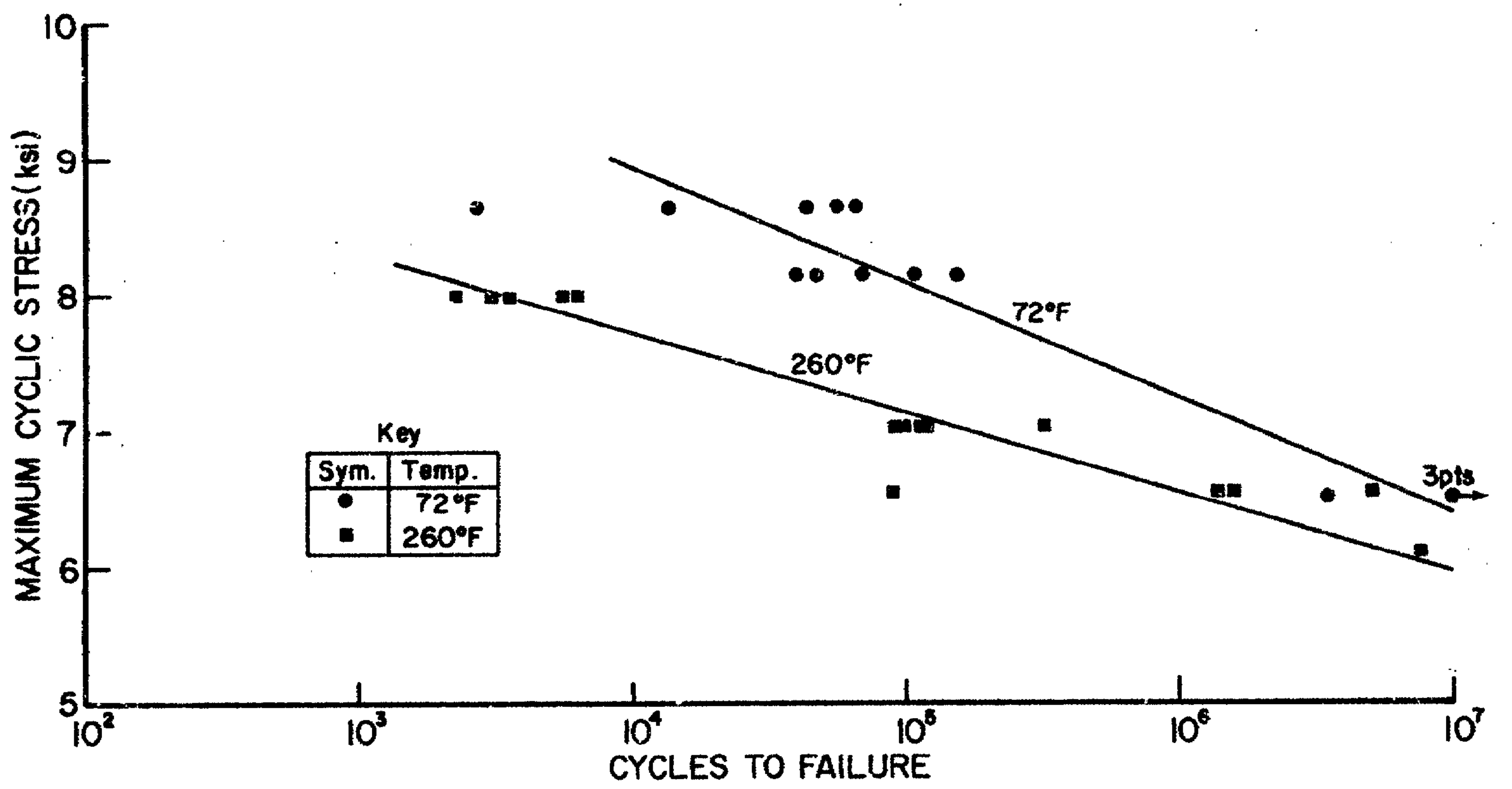


Figure 55 . Tensile-Tensile Fatigue Behavior of Bidirectional HyE 2034D Composite Laminates: ±45° Fiber Orientation, R = 0.10, 10 Hz.

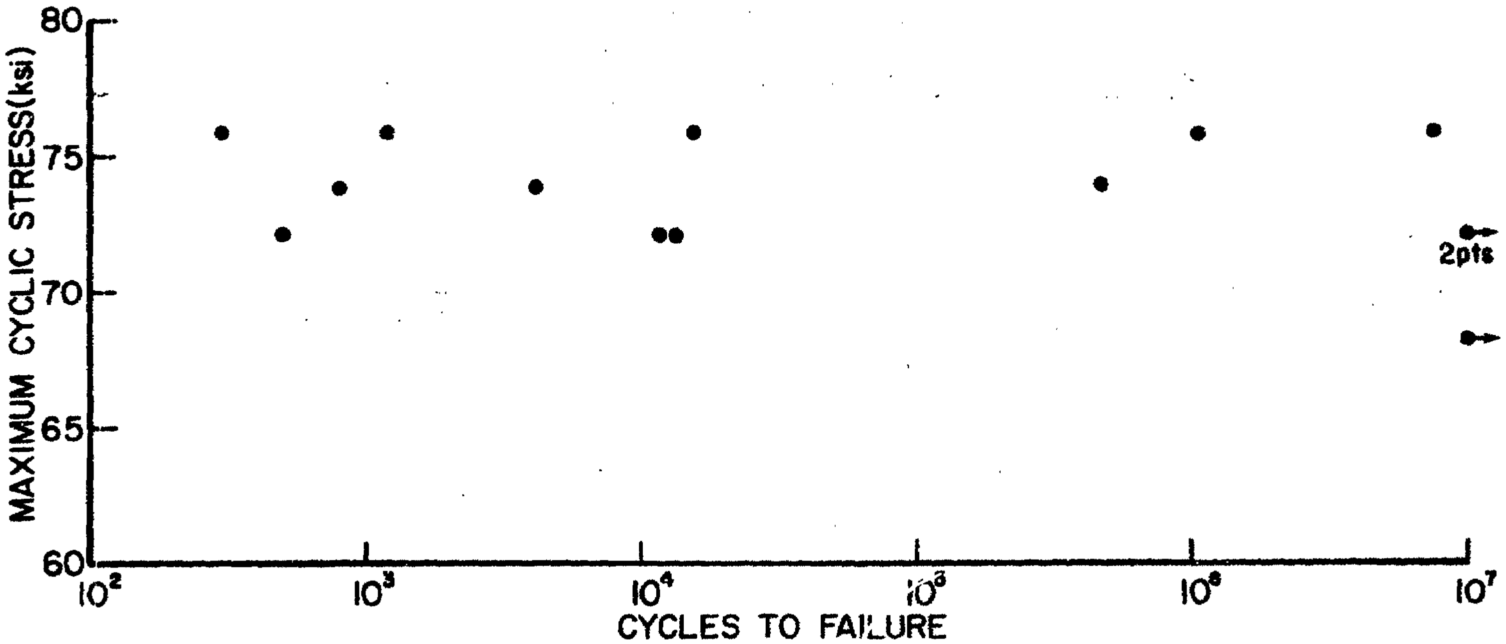


Figure 56. Tensile-Tensile Fatigue Behavior of Multidirectional HyE 2034D Composite Laminates at 72°F (22°C): $(0,45,-45,0,0,-45,45,0,90,0)_s$ Fiber Orientation, R = 0.10, 10 Hz.

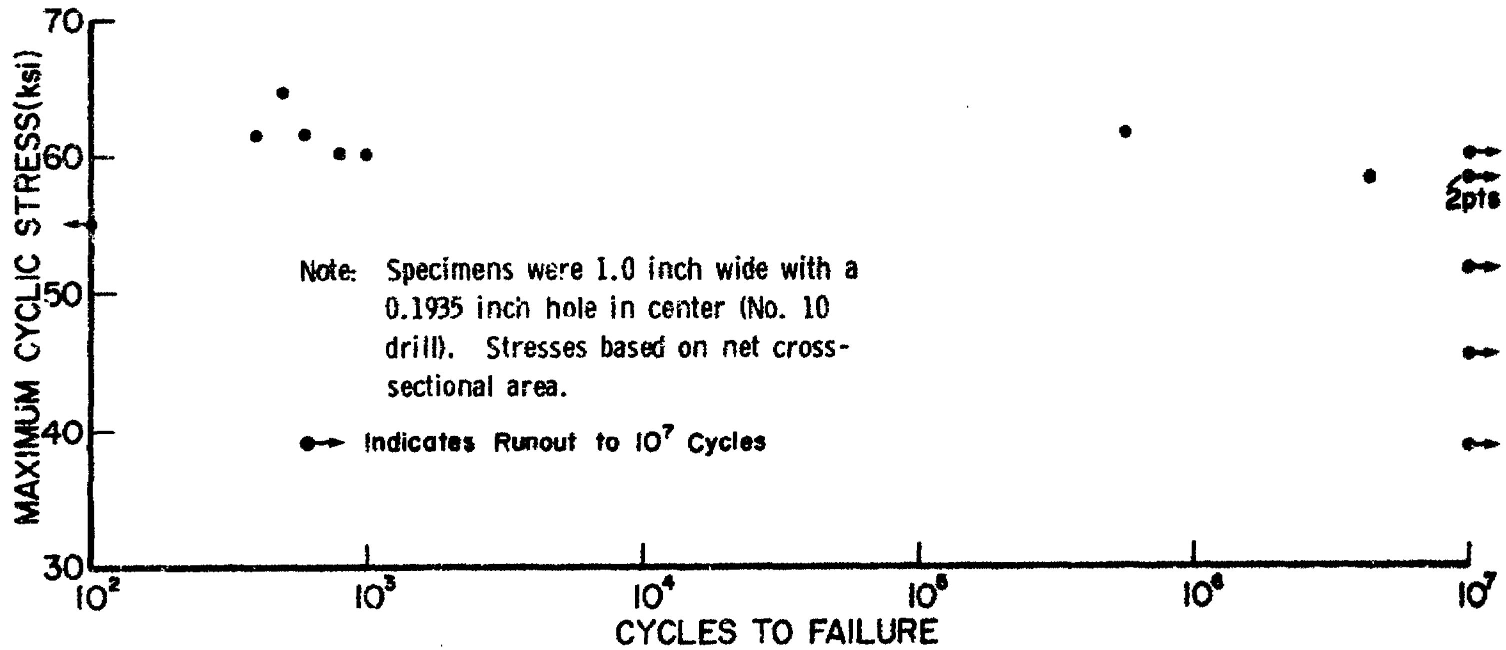


Figure 57. Tensile-Tensile Fatigue Behavior of Multidirectional HyE 2034D Composite Laminates at 72°F (22°C): $(0,45,-45,0,0,-45,45,0,90,0)_s$ Fiber Orientation, R = 0.10, 10 Hz.

TABLE 45

THERMOPHYSICAL PROPERTIES OF HyE2034D COMPOSITE LAMINATES

Composite Material Properties

Material System - HyE 2034D	Prepreg by - Fiberite	HMG/Epoxy

Fiber - VSC-32 Matrix - 934
Maximum Temperature Rating - 350°F(177°C)
Resin Content - 26.5% by wt.
Fiber Content - 65.7% by vol.
Void Content - ~0
Thickness of each type specimen: Therm. Exp. - 40 ply; Therm. Cond. - 40 ply; Spec. Ht. - 1 ply; Glass Trans. - 8 ply

Laminate Sp. Gr. - 1.79
Average Ply Thickness - 0.0050 inch
No. of panels from which specimens were tested in this table - 3

THERMOPHYSICAL PROPERTIES: 0°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)	Test Method
Thermal Expansion[1]					
α_x [μin/in-°F](μcm/cm-°C)	[-0.68](-1.22	[-0.86](-1.54	[-0.89](-1.61)	[-1.08](-1.94)	TMA[2]
α_y [μin/in-°F](μcm/cm-°C)	[32.1](57.8)	[22.0](39.6)	[17.0](30.6)	[15.1](27.1)	
No. of Specimens per direction	3	3	3	3	
Specific Heat					DSC[3]
C_p [btu/lb.-°F](J/kg-°C)	[0.110](460)	[0.202](846)	[0.642](2689)	[0.718](3010)	
No. of Specimens	3	3	3	3	
Thermal Conductivity[1]					
k_z [btu-ft/ft^2-hr-°F] (W/m-°C)	[0.52] (0.89)	[0.67] (1.16)	[0.89] (1.53)	[0.99] (1.70)	Comparative
No. of Specimens	3	3	3	3	
Glass Transition Temp.					DMA[4]
Dry [°F](°C)	[430](221)				
Wet [°F](°C)	[342](172)				

THERMOPHYSICAL PROPERTIES: ±45°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)	Test Method
Thermal Expansion[1]					
α_x [μin/in-°F](μcm/cm-°C)	[-0.15](-0.27	[-0.22](-0.40)	[-0.36](-0.64	[-0.49](-0.89	TMA[2]
No. of Specimens per direction	3	3	3	3	
Thermal Conductivity[1]					Comparative
k_z [btu-ft/ft^2-hr-°F] (W/m-°C)	[0.55] (0.94)	[0.56] (0.96)	[0.57] (0.99)	[0.59] (1.01)	
No. of Specimens	3	3	3	3	

NOTES: 1. On the unidirectionally reinforced specimens, the x-direction is along the fiber axis, the y-direction is across the fiber axis, and the z-direction is through the thickness (identical to the y-direction). On ±45° bidirectionally reinforced specimens, the x and y directions are identical and oriented at 45° to either fiber direction, while the z-direction is through the thickness.
2. Thermo-mechanical analysis.
3. Differential scanning calorimetry.
4. Dynamic mechanical analysis.

TABLE 46

PRELIMINARY ACCUMULATED DATA FOR HyE 2034D[1]

HyE 2034D (75 million modulus pitch) tested by various companies under different cure cycle and testing procedures. All mechanical test values, except shear, are normalized to 60% fiber volume. All testing was performed at room temperature.

	Fiberite	TRW	Ryan	G.D. Convair[2]	G.D. Convair[3]
F_{fu} - Ksi	99	95	84	91/--	85/--
E_f - Msi	37	39	34[4]	-----	33/--
F_{su} - Ksi	10	8	9	9/--	7/--
F_{tu} - Ksi	110	121	123	108/39	87/32
E_t - Msi	46	43	47	44/15	46/15
F_{cu} - Ksi			54[5]		
E_c - Msi			38[5]		

[1]All information in this table provided by FIBERITE.

[2]Cure cycle 1, $(0°)_{12}/(0, 45, 90, 135)_s$
Apply vacuum at R.T., heat at 3°F/minute to 250 ± 5°F, hold 30 minutes, apply 100 psig, hold an additional 30 minutes, heat at 3°F/minute to 275 ± 5°F. Hold six hours, cool to below 150°F at a rate not to exceed 5°F/minute under vacuum and 100 psig, debag and free stand postcure for 20 hours at 275 ± 5°F.

[3]Cure cycle 2, $(0°)_{12}/(0, 45, 90, 135)_s$
Apply vacuum at R.T., heat at 3°F/minute to 250 ± 5°F, hold 45 minutes, apply 100 psig, hold an additional 45 minutes, heat at 3°F/minute to 350 ± 5°F, hold two hours. Cool to below 150°F at a rate not to exceed 5°F/minute under vacuum and 100 psig.

[4]May be in error due to deflectometer troubles.

[5]Celanese compression tests.

4.4 T300/V378A

This graphite/polyimide system is based on a resin matrix system developed by U.S. Polymeric.

Tables 47 through 59 present the data generated for this nominal 450°F (232°C) graphite/polyimide system. Figures 58 through 73 illustrate the stress-strain, fatigue, and creep behavior of the material as well as the effects of humidity aging upon selected composite properties.

Probably the most unusual characteristic of this system is the very noticeable odor of the prepreg. This arises from a volatile reactive constituent in the resin and not only is offensive to those working with the prepreg, but also results in an abbreviated out-life for the prepreg. When a sufficient amount of this volatile reactant has vaporized, good quality laminates can no longer be fabricated. The substantial differences between the HPLC analyses on new and old V378A prepreg presented in Appendix B (pages 279 and 280) illustrate the dramatic changes undergone by the resin system even in 0°F (-18°C) storage. The first five peaks in the HPLC are very significantly reduced on the old material, while the last three have disappeared completely.

TABLE 47

PROCESSING CONDITIONS FOR T300/V378A
COMPOSITE LAMINATES

Composite Processing Information	
Material System - V373A Fiber - T300 w/epoxy size Matrix - V378A Maximum Rated Temperature - 450°F (232°C)	Gr/PI Prepreg by -U.S. Polymeric

Laminate Processing Schedule

Layup Procedure: The prepreg was stored in a closed wrapper at 0°F (-18°C). Prepreg was warmed to room temperature before removal from wrapper to prevent moisture condensation on prepreg. Plies were cut to desired size with razor knife and stacked in desired sequence (release paper removed) from each ply). The stack was placed in the autoclave according to the layup system illustrated in Figure 58. The corprene edge dam serves to restrict fiber flow.

Cure Schedule: Apply full vacuum and 85 psi above bladder at room temperature. Heat to 175°F (80°C) at a rate of ~4°F/min. Vent vacuum at 175°F (180°C) and hold at temperature for 2 hours. Heat up to 355°F (180°C) at a rate of ~4°F/min. and hold at 355°F (180°C) for 4 hours. Reduce pressure to 10 psi then cool to below 150°F (66°C). Remove panel from autoclave and start postcure.

Postcure Schedule: Heat to 475°F (246°C) and hold for 4 hours. Increase temperature to 550°F (288°C) and hold for 1 hour. Cool panels to below 150°F (66°C) and remove.

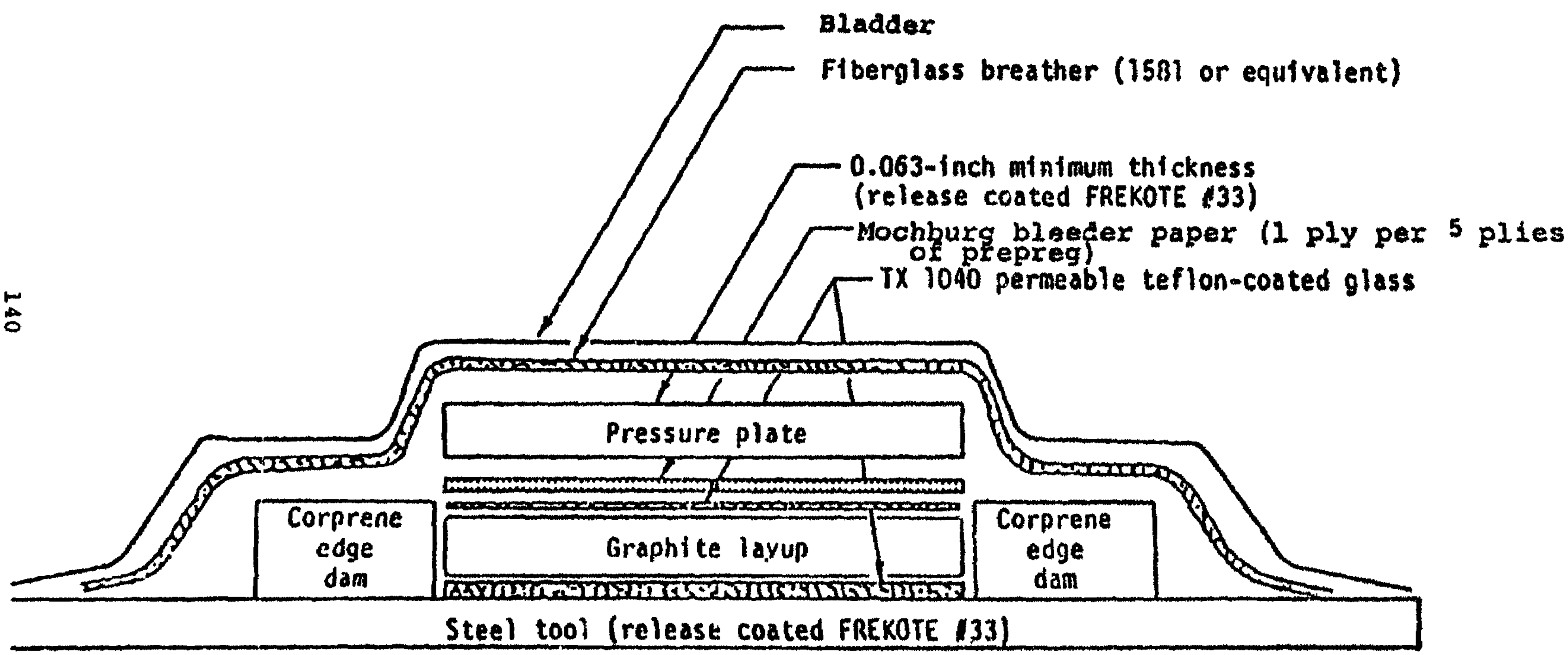


Figure 58. Layup System for V378A Laminates.

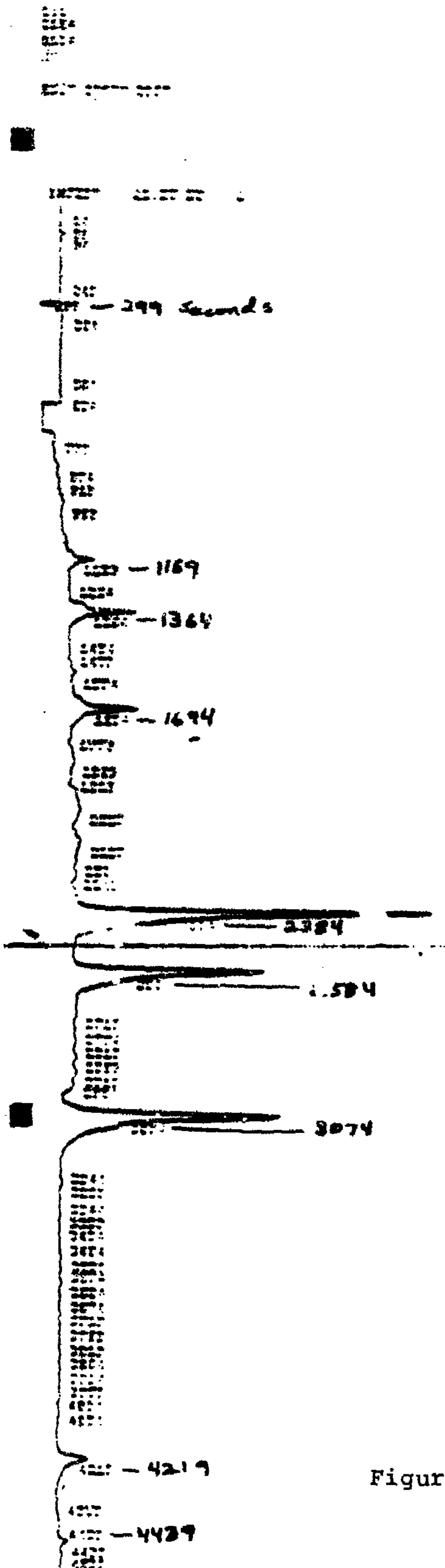
TAPLE 48

PREPREG AND COMPOSITE PHYSICAL PROPERTIES

Composite Physical Property Information				
Material System - T300/V378A Fiber - T300 Matrix - V378A Maximum Rated Temperature - 450°F(232°C)			Gr/Polyimide Prepreg by -U.S. Polymeric	
Prepreg Physical Properties				
(Property)	(Stnd.Dev.)	(Range)	(Test Method)	(Ref.)
Volatile Content-5.5% by wt.	0.8%	4.6-6.1	QCI-C-V-14	Fiberite
Resin Content- 30.6% by wt.	1.8%	29.0-32.6	R-15	Fiberite
Gel Time - 32.2 min@210°F	0.3 min	32.0-32.5	G-2	Fiberite
No. of Rolls Involved- 1				
No. of Batches Involved- 1				
Laminate Physical Properties[1]				
	(Stnd.Dev.)	(Range)	(Test Method)	(Ref.)
No. of Panels- 36				
Fiber Content- 67.0% by wt.	2.2%	6.34-71.1%	see footnote 2	
Resin Content- 25.6% by wt.	2.2%	21.7-29.7%		
Void Content- 1.4 % by vol.	1.2%	0-4.3%	D 2734	ASTM
Laminate Sp. Gr.- 1.58	0.02	1.53-1.61	D792	ASTM
Fiber Sp. Gr.- 1.75	As reported by manufacturer.			
Matrix Sp. Gr.- 1.27	As reported by manufacturer.			
Thickness per ply- 0.0051 inch (0.13 mm)			---	---

[1]The properties reported here represent averages for all panels of this material used throughout the program.

[2]An acid digestion method similar to that described in AFML-TR-67-243 was used with the following materials and temperatures. A mixture of concentrated sulfuric acid and hydrogen peroxide (30%) in the ratio of 80% to 20% by volume respectively was used as the digesting acid. The specimens were soaked in this solution at 375-400°F (190-204°C) until the acid turned dark. The acid was drained, the specimen rinsed, and fresh acid added. This sequence was repeated until the acid did not discolor and the residual fiber weight reached equilibrium.



HPLC ANALYSIS

SAMPLE (CONC.) V378A - New* 0.1%	SAMPLE SIZE 25 ul
MOBILE PHASE 1 H_2O	MOBILE PHASE 2 Dioxane
FLOW RATE 1.0 ml/min	PROGRAM Meth C
COLUMN(S) RP-8 (SP)	DETECTOR Tracor-UV
ATTENUATION 16	WAVE LENGTH 254
CHART SPEED 0.5 cm/min	FULL SCALE (mV) 40
DATE 10-2-80	OPERATOR B. Price

* 1 month storage at 0°F

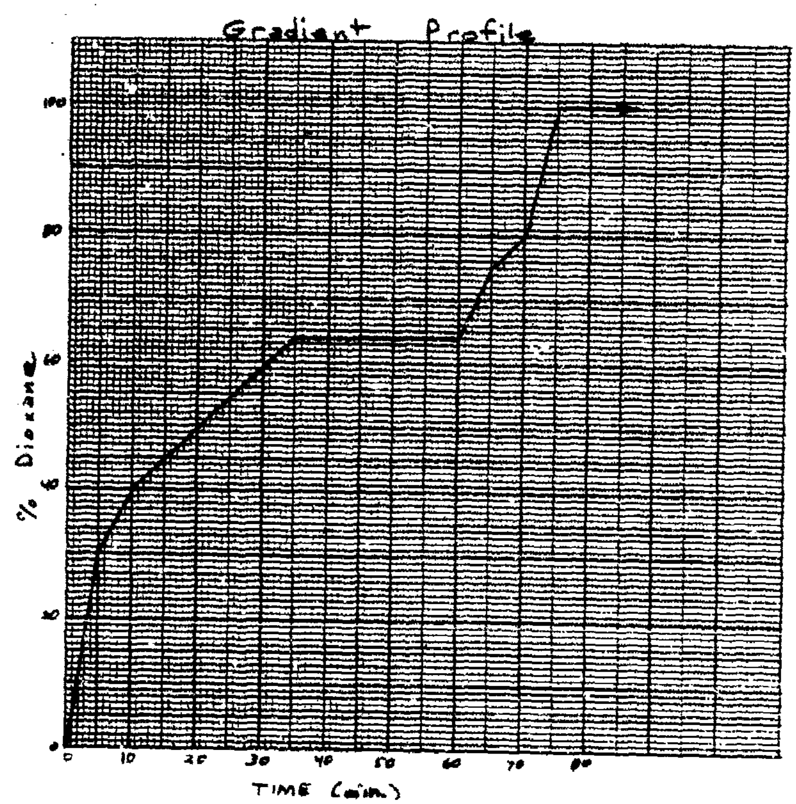


Figure 59. HPLC Analysis of V378A.

TABLE 49

TENSILE PROPERTIES OF T300/V378A COMPOSITE LAMINATES

Composite Material Properties				
Material System - T300/V378A; Prepreg by - U.S. Polymeric; Fiber - T300; Matrix - V378A; Maximum Rated Temperature - 450°F(232°C); Resin Content - 25.6% by wt.; Fiber Content - 67.1% by vol.; Void Content - 1.1% by vol.; Thickness of each type specimen: 0° - 6 ply ; 90° - 15 ply	Laminate Sp. Gr. - 1.58; Nominal Ply Thickness - 0.0052 inch(0.13 mm); No. of panels from which specimens were tested in this table - 7			Gr/PI
TENSION: 0°				
	-67°F(-55°C)	72°F(22°C)	350°F(177°C)	450°F(232°C)
F_x^{tu} [ksi](MPa)	[222.3](1532)	[230.2] (1586)	[210.1] (1448)	[217.3] (1497)
Stnd.Dev. [ksi](MPa)	[31.7] (218)	[25.0] (172)	[23.4] (161)	[15.3] (105)
Range [ksi](MPa)	[172.4 - 250.0] (1188 - 1722)	[189.7 - 250.6] (1307 - 1727)	[103.9 - 239.4] (1267 - 1649)	[200.8-240.3] (1384 - 1656)
No. of Specimens	5	5	5	5
F_x^{tpl} [ksi](MPa)	[222.3] (1532)	[230.2] (1586)	[210.1] (1648)	[217.3] (1497)
Stnd.Dev. [ksi](MPa)	[.31.7] (218)	[25.0] (172)	[23.4] (161)	[15.3] (105)
No. of Specimens	5	5	5	5
E_x^t [Msi] (GPa)	[20.0] (138)	[20.1] (138)	[22.1] (152)	[18.8] (130)
Stnd.Dev. [Msi] (GPa)	[0.6] (4.3)	[0.4] (3.1)	[1.5] (10)	[1.1] (8)
No. of Specimens	5	5	5	5
ε_x^{tu} [μin/in](μcm/cm)	10,130	10,510	9,770	11,180
Stnd.Dev.	1,900	1,400	8,000	506
No. of Specimens	5	5	5	5
ν_{xy}^t	0.31	0.30	0.33	0.32
Stnd. Dev.	0.02	0.03	0.03	0.04
No. of Specimens	5	5	5	5
Test Method Reference	Straight-sided tension ASTM D3039			
TENSION: 90°				
F_y^{tu} [ksi](MPa)	[5.82] (40)	[5.37] (37)	[4.84] (33)	[4.21] (29)
Stnd.Dev. [ksi](MPa)	[0.91] (6.3)	[0.55] (3.8)	[0.38] (2.6)	[0.57] (3.9)
Range	[4.68 - 6.68] (32 - 46)	[4.74 - 6.11] (33 - 42)	[4.02 - 4.97] (27 - 34)	[3.48 - 4.69] (24 - 32)
No. of Specimens	5	5	5	5
F_y^{tpl} [ksi](MPa)	[5.82] (40)	[3.55] (24)	[3.62] (25)	[2.55] (18)
Stnd.Dev. [ksi](MPa)	[0.91] (6.3)	[0.94] (6.5)	[0.35] (2.4)	[0.64] (4.4)
No. of Specimens	5	5	5	5
E_y^t [Msi] (GPa)	[1.40] (9.6)	[1.31] (9.0)	[1.07] (7.4)	[1.00] (6.9)
Stnd.Dev. [Msi] (GPa)	[0.01] (0.07)	[0.03] (0.2)	[0.03] (0.2)	[0.02] (0.1)
No. of Specimens	5	5	5	5
ε_y^{tu} (μin/in)(μcm/cm)	4,345	4,140	4,130	4,290
Stnd. Dev.	600	410	390	630
No. of Specimens	5	5	5	5
ν_{yx}^t	0.022[1]	0.020[1]	0.016[1]	0.017[1]
Stnd. Dev.	—	—	—	—
No. of Specimens	—	—	—	—
Test Method Reference	Straight-sided tension ASTM D3039			

[1] Computed using elastic moduli and longitudinal Poisson's ratio.

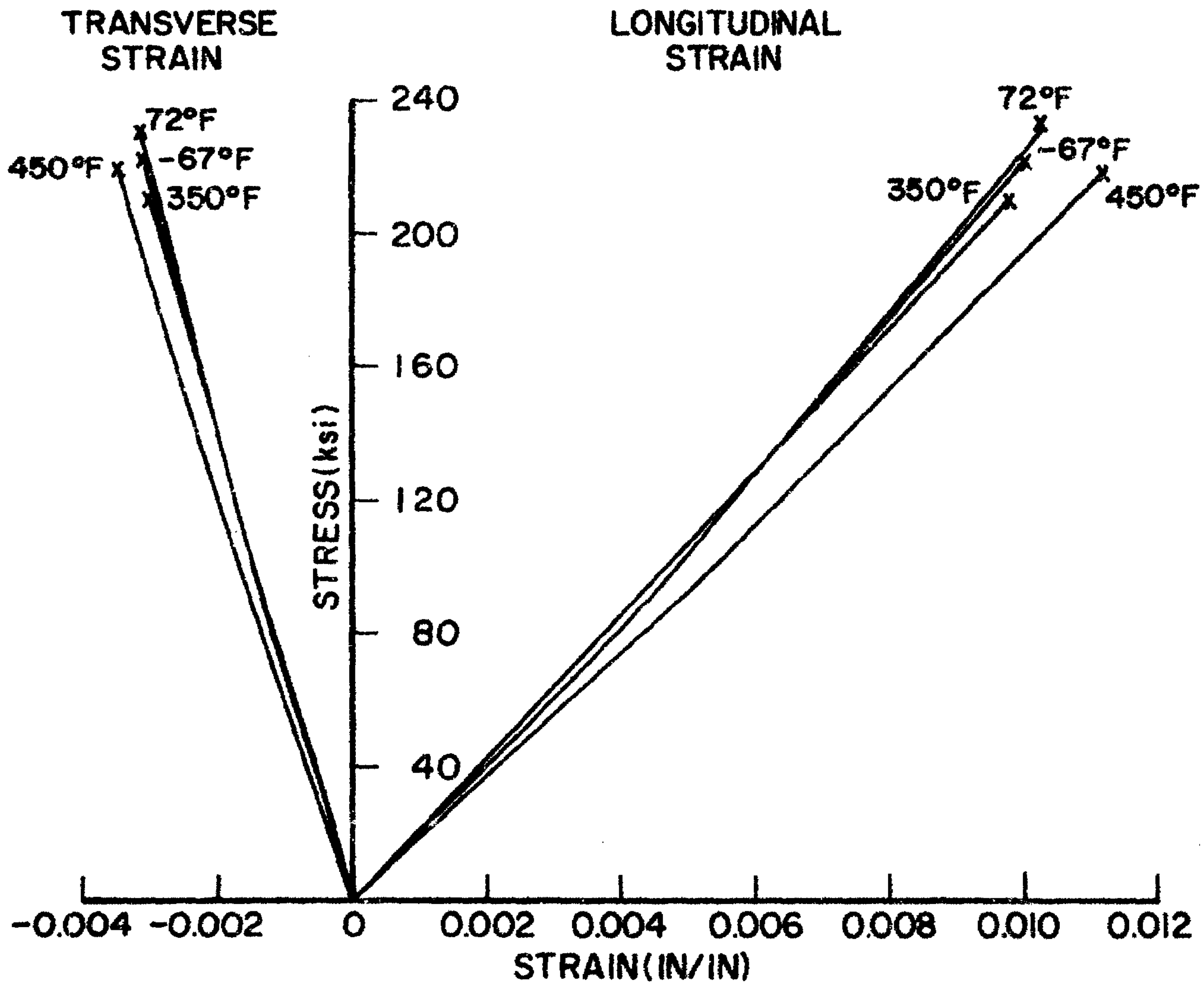


Figure 60. Tensile Stress-Strain Curve for Unidirectional T300/V378A Composite Laminates: 0° Fiber Orientation.

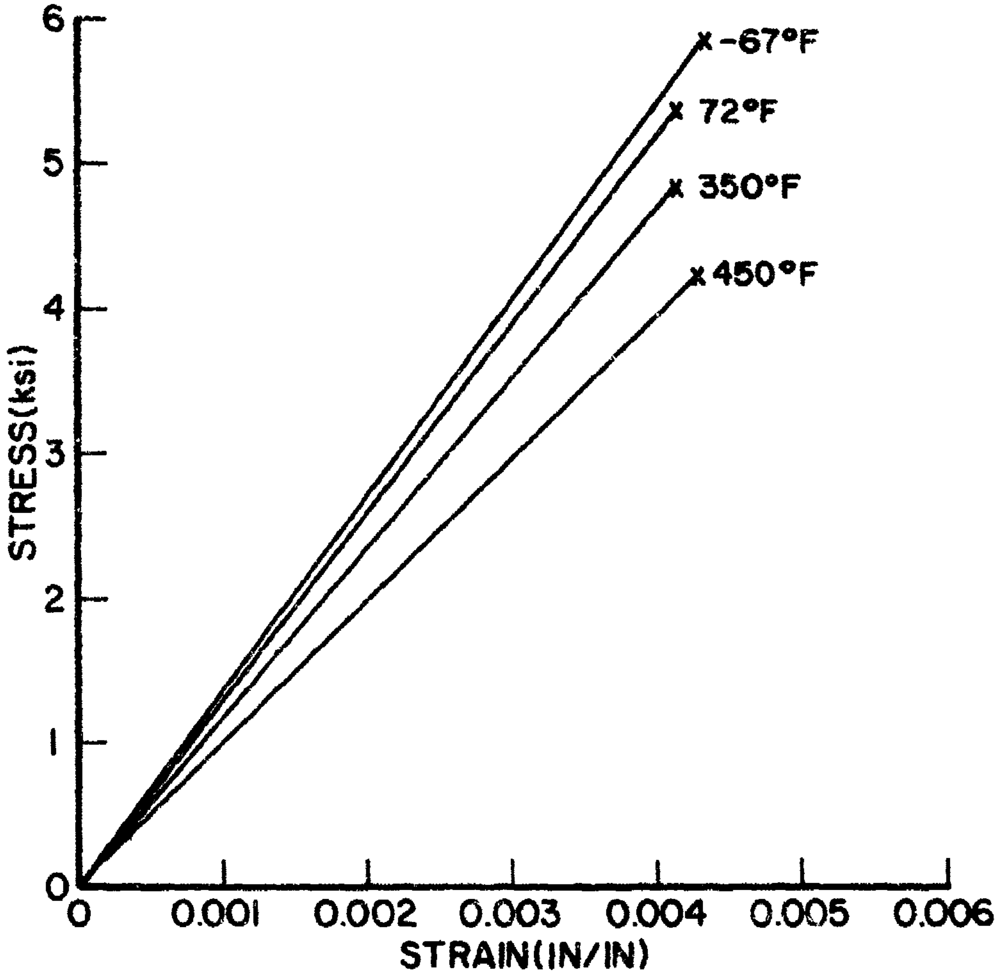


Figure 61. Tensile Stress-Strain Curves for Unidirectional T300/V378A Composite Laminates: 90° Fiber Orientation.

TABLE 50

TENSILE PROPERTIES OF T300/V378A COMPOSITE LAMINATES

Composite Material Properties				
Material System - T300/V378A; Prepreg by - U.S. Polymeric; Fiber - T300; Matrix - V378A; Maximum Rated Temperature - 450°F(232°C); Resin Content - 26.9% by wt.; Fiber Content - 66.1% by vol.; Void Content - 0.8% by vol.	Gr/Polyimide; Laminate Sp. Gr. - 1.59; Nominal Ply Thickness - 0.0052 inch(0.13 mm); No. of panels from which specimens were tested in this table - 8; Thickness of specimen - 8 ply			
TENSION: ±45°				
	-67°F(-55°C)	72°F(22°C)	350°F(177°C)	450°F(232°C)
F_x^{tu} [ksi](MPa)	[21.52] (148)	[21.29] (147)	[16.12] (111)	[14.94] (103)
Stnd.Dev. [ksi](MPa)	[1.17] (8.1)	[1.29] (8.9)	[0.69] (4.8)	[0.34] (2.3)
Range [ksi](MPa)	[20.33 - 23.12] (140 - 159)	[19.18-22.14] (132-153)	[14.96-16.77] (103-116)	[14.46 - 15.41] (100 - 106)
No. of Specimens	5	5	5	5
F_x^{tpl} [ksi](MPa)	[8.32] (57)	[6.35] (44)	[4.49] (31)	[3.46] (24)
Stnd.Dev. [ksi](MPa)	[0.83] (5.7)	[0.67] (4.6)	[0.59] (4.1)	[0.73] (5.0)
No. of Specimens	5	5	5	5
E_x^t [Msi](GPa)	[3.13] (22)	[2.96] (20)	[2.54] (18)	[2.16] (15)
Stnd.Dev. [Msi](GPa)	[0.16] (1.1)	[0.03] (0.2)	[0.13] (0.9)	[0.11] (0.8)
No. of Specimens	5	5	5	5
ϵ_x^{tu} [μin/in](μcm/cm)	9,020	12,100	27,070	20,320
Stnd. Dev.	930	140	11,020	230
No. of Specimens	5	5	5	5
ν_{xy}^t	0.70	0.59	1.00	0.82
Stnd. Dev.	0.05	0.04	0.07	0.03
No. of Specimens	5	5	4	5
Test Method	Straight-sided tension			
Reference	ASTM D3039			

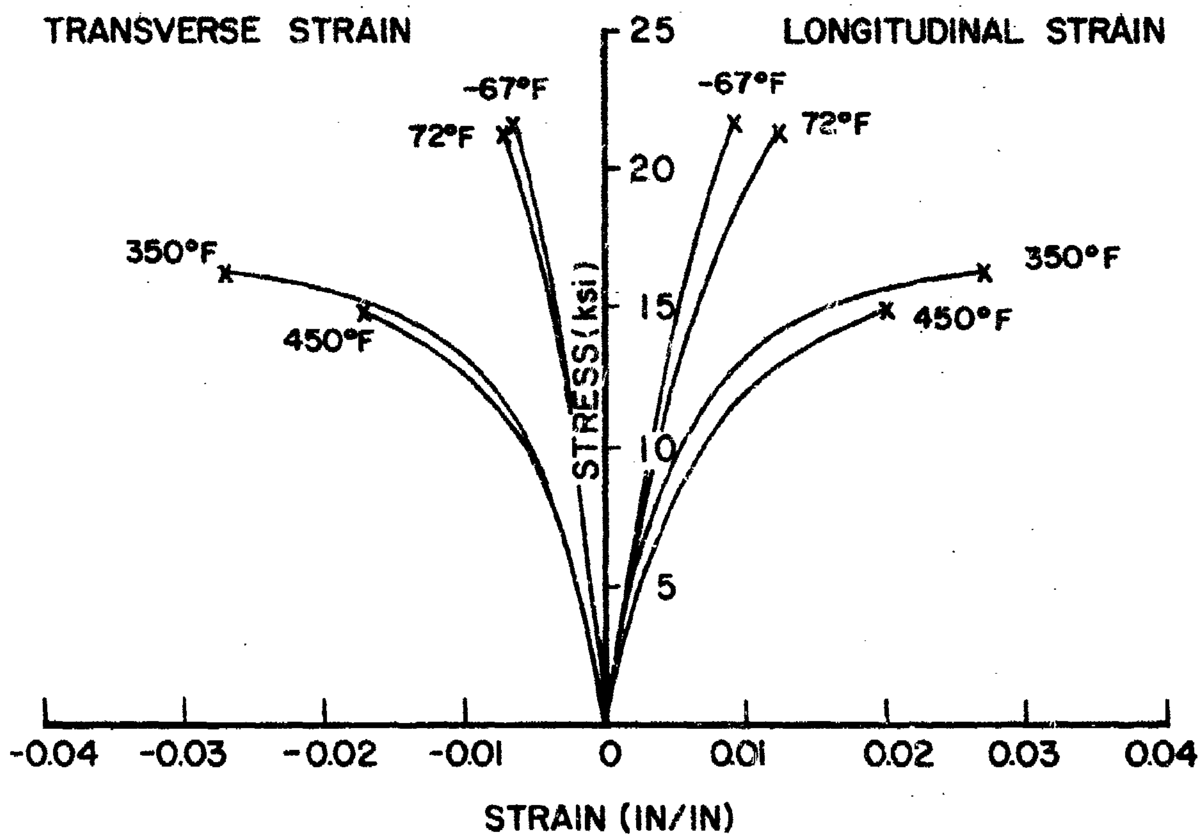


Figure 62. Tensile Stress-Strain Curves for Bidirectional T300/V378A Composite Laminates: ±45° Fiber Orientation.

TABLE 51

TENSILE PROPERTIES OF T300/V378A COMPOSITE LAMINATES

Composite Material Properties

Material System - T300/V378A
Fiber - T300 Matrix - V378A
Maximum Rated Temperature - 450°F(232°C)
Resin Content - 25.7% by wt.
Fiber Content - 66.6% by vol.
Void Content - 1.8% by vol.
Thickness of each type specimen: 20 ply

Prepreg by - U.S. Polymeric | Gr/Polyimide

Laminate Sp. Gr. - 1.57
Nominal Ply Thickness - 0.0053 inch (0.13 mm)
No. of panels from which specimens were tested in this table - 13

TENSION: $(0, +45, -45, 0, 0, -45, +45, 0, 90, 0)_s$

	-67°F(-55°C)	72°F(22°C)	350°F(177°C)	450°F(232°C)
F_x^{tu} [ksi](MPa)		[119.7] (825)	[106.1] (731)	[107.5] (741)
Stnd.Dev. [ksi](MPa)		[12.8] (88)	[11.4] (79)	[12.1] (83)
Range [ksi](MPa)		[102.6-130.4] (707 - 898)	[90.3 - 119.6] (622 - 824)	[88.9 - 119.2] (613 - 821)
No. of Specimens		5	5	5
F_x^{tpl} [ksi](MPa)		[119.7] (825)	[106.1] (731)	[107.5] (741)
Stnd.Dev. [ksi](MPa)		[12.8] (88)	[11.4] (79)	[12.1] (83)
No. of Specimens		5	5	5
E_x^t [Msi](GPa)		[13.96] (96)	[13.41] (92)	[13.15] (91)
Stnd.Dev. [Msi](GPa)		[1.13] (7.8)	[2.43] (16.7)	[0.80] (5.5)
No. of Specimens		5	5	5
ε_x^{tu} [µin/in](µcm/cm)		10,590	9,030	9,380
Stnd.Dev.		270	910	1,463
No. of Specimens		5	5	5
ν_{xy}^t		0.59	0.62	0.52
Stnd. Dev.		0.05	0.07	0.11
No. of Specimens		5	5	5
Test Method Reference		ASTM D3039		

TENSION: $(0, +45, -45, 0, 0, -45, +45, 0, 90, 0)_s$ with 0.1935 inch(0.491 cm) hole

	-67°F(-55°C)	72°F(22°C)	350°F(177°C)	450°F(232°C)
F_y^{tu} [ksi](MPa)		[93.1] (641)		
Stnd.Dev. [ksi](MPa)		[14.2] (98)		
Range		[79.9-112.5] (551 - 775)		
No. of Specimens		5		
F_y^{tpl} [ksi](MPa)				
Stnd.Dev. [ksi](MPa)				
No. of Specimens				
E_y^t [Msi] (GPa)				
Stnd.Dev. [Msi] (GPa)				
No. of Specimens				
ε_y^{tu} [µin/in](µcm/cm)				
Stnd. Dev.				
No. of Specimens				
ν_{yx}^t				
Stnd. Dev.				
No. of Specimens				
Test Method Reference				

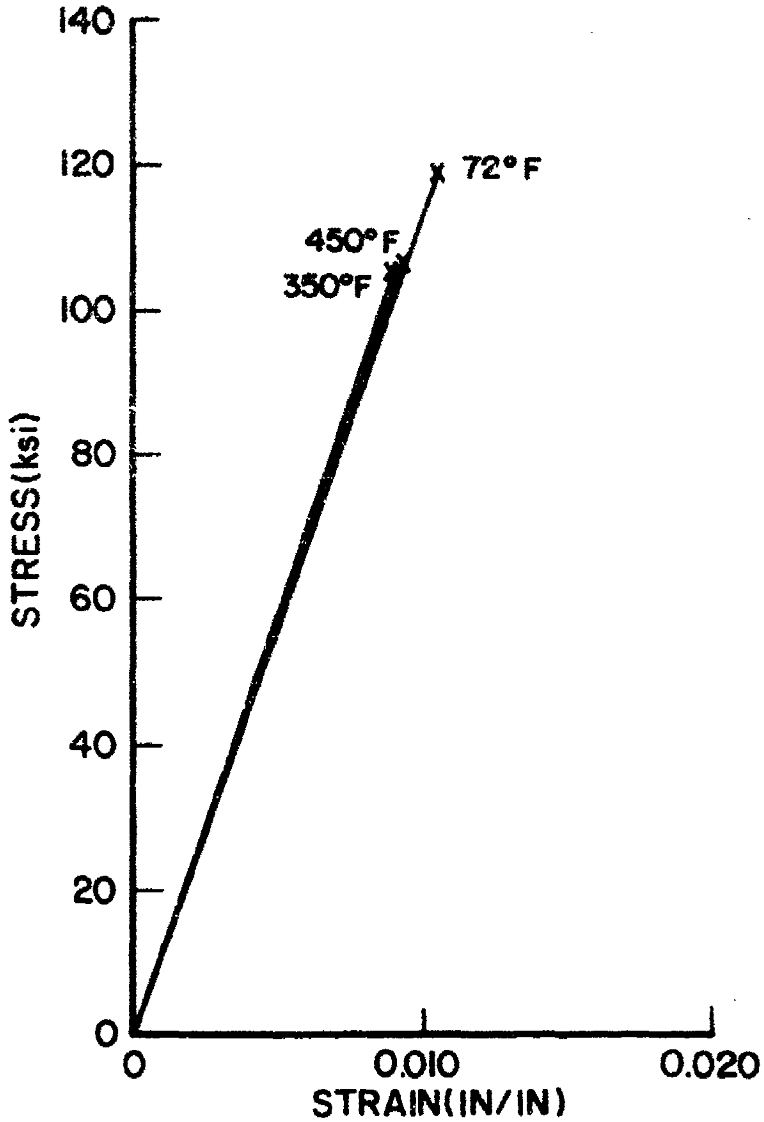


Figure 63 . Tensile Stress-Strain Curves for Multidirectional T300/V378A Composite Laminates: $(0,45,-45,0,0,-45,45,0,90,0)_s$ Fiber Orientation.

TABLE 52

COMPRESSIVE PROPERTIES OF T300/V378A COMPOSITE LAMINATES

Composite Material Properties

Material System - T300/V378A	Prepreg by - U.S. Polymeric
Fiber - T300 Matrix - V378A	Gr/Polyimide
Maximum Rated Temperature - 450°F(232°C)	Laminate Sp. Gr. - 1.60
Resin Content - 24.2% by wt.	Nominal Ply Thickness - 0.0050 inch (0.13 mm)
Fiber Content - 69.1% by vol.	No. of panels from which specimens were tested in this table - 2
Void Content - 0.8% by vol.	
Thickness of each type specimen: 0° - 20 ply ; 90° - 20 ply	

COMPRESSION: 0°

	-67°F(-55°C)	72°F(22°C)	350°F(177°C)	450°F(232°C)
F_x^{cu} [ksi](MPa)	[213.4] (1470)	[192.6] (1327)	[162.1] (1117)	[100.6] (693)
Stnd.Dev. [ksi](MPa)	[17.9] (123)	[16.0] (110)	[22.4] (154)	[26.4] (182)
Range [ksi](MPa)	[189.7-238.1] (1307-1640)	[168.5-212.8] (1161-1466)	[136.8-195.0] (943-1344)	[79.4 - 145.9] (547 - 1003)
No. of Specimens	5	5	5	5
F_x^{cpl} [ksi](MPa)	[45.3] (312)	[140.0] (965)	[123.3] (850)	[85.5] (589)
Stnd.Dev. [ksi](MPa)	[15.0] (103)	[83.3] (574)	[50.5] (348)	[44.6] (307)
No. of Specimens	5	5	5	5
E_x^c [Msi](GPa)	[19.6] (135)	[19.8] (136)	[23.4] (161)	[20.8] (143)
Stnd.Dev. [Msi](GPa)	[1.7] (12)	[0.6] (4)	[1.4] (10)	[2.3] (16)
No. of Specimens	5	5	5	5
ε_x^{cu} [μin/in](μcm/cm)	12,940+[1,2]	16,120+[1,3]	8,120	5,140
Stnd. Dev.	5,490	3,170	2,760	1,530
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3410			

COMPRESSION: 90°

	-67°F(-55°C)	72°F(22°C)	350°F(177°C)	450°F(232°C)
F_y^{cu} [ksi](MPa)	[37.9] (261)	[26.8] (185)	[19.0] (131)	[20.2] (139)
Stnd.Dev. [ksi](MPa)	[11.6] (80)	[2.1] (14)	[2.1] (14)	[3.2] (22)
Range	[28.2-54.7] (194-377)	[24.4-28.5] (168-196)	[16.2-21.8] (112-150)	[17.6 - 25.5] (121 - 155)
No. of Specimens	5	5	5	5
F_y^{cpl} [ksi](MPa)	[16.1] (111)	[5.9] (41)	[5.2] (36)	[6.8] (47)
Stnd.Dev. [ksi](MPa)	[13.2] (91)	[2.3] (16)	[1.5] (10)	[6.5] (45)
No. of Specimens	5	5	5	5
E_y^c [Msi](GPa)	[2.5] (17)	[2.5] (17)	[1.6] (11)	[1.2] (8)
Stnd.Dev. [Msi](GPa)	[1.0] (7)	[0.9] (6)	[0.3] (2)	[0.1] (1)
No. of Specimens	5	5	5	5
ε_y^{cu} [μin/in](μcm/cm)	23,360+[1,3]	23,820+[1,4]	13,820+[1,2]	18,880+[1,5]
Stnd. Dev.	7,170	7,820	4,260	16,870
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3410			

[1] Ultimate strain values represent maximum observed strain rather than ultimate values.
[2] Three of five specimens exhibited evidence of buckling.
[3] One of five specimens exhibited evidence of buckling.
[4] All five specimens exhibited evidence of buckling.
[5] Two of five specimens exhibited evidence of buckling.

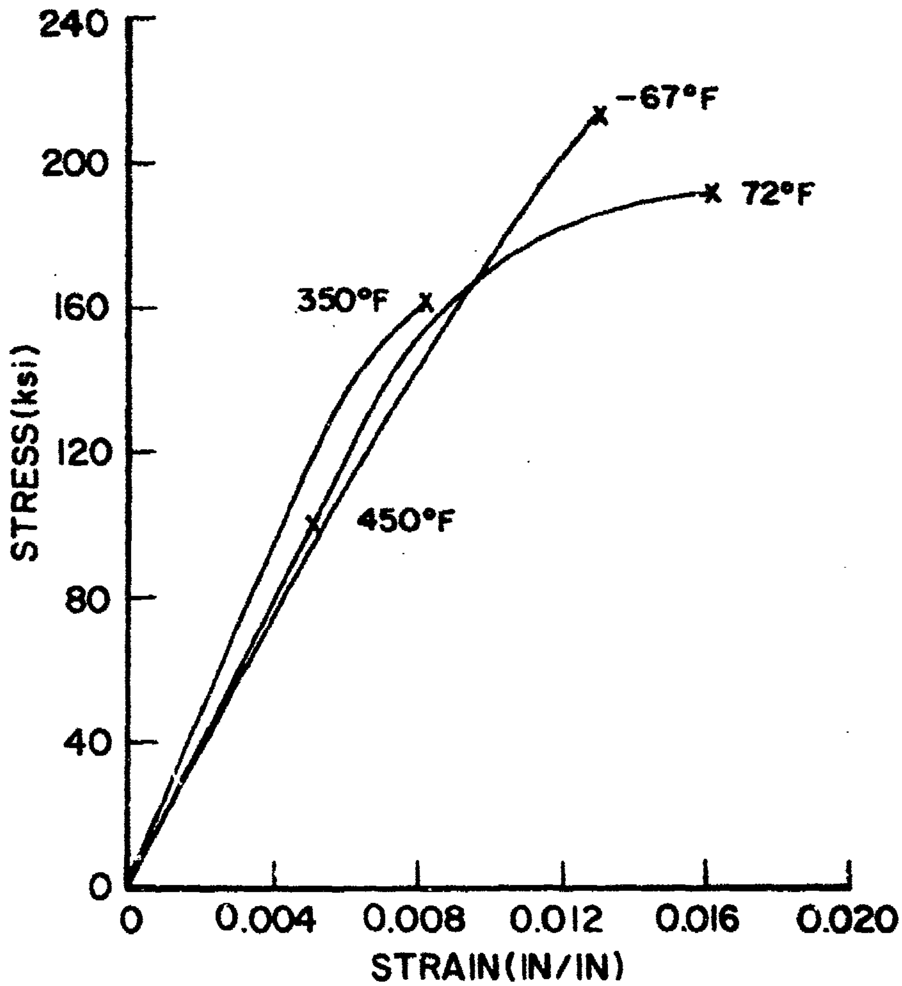


Figure 64. Compressive Stress-Strain Curves for Unidirectional T300/V378A Composite Laminates: 0° Fiber Orientation.

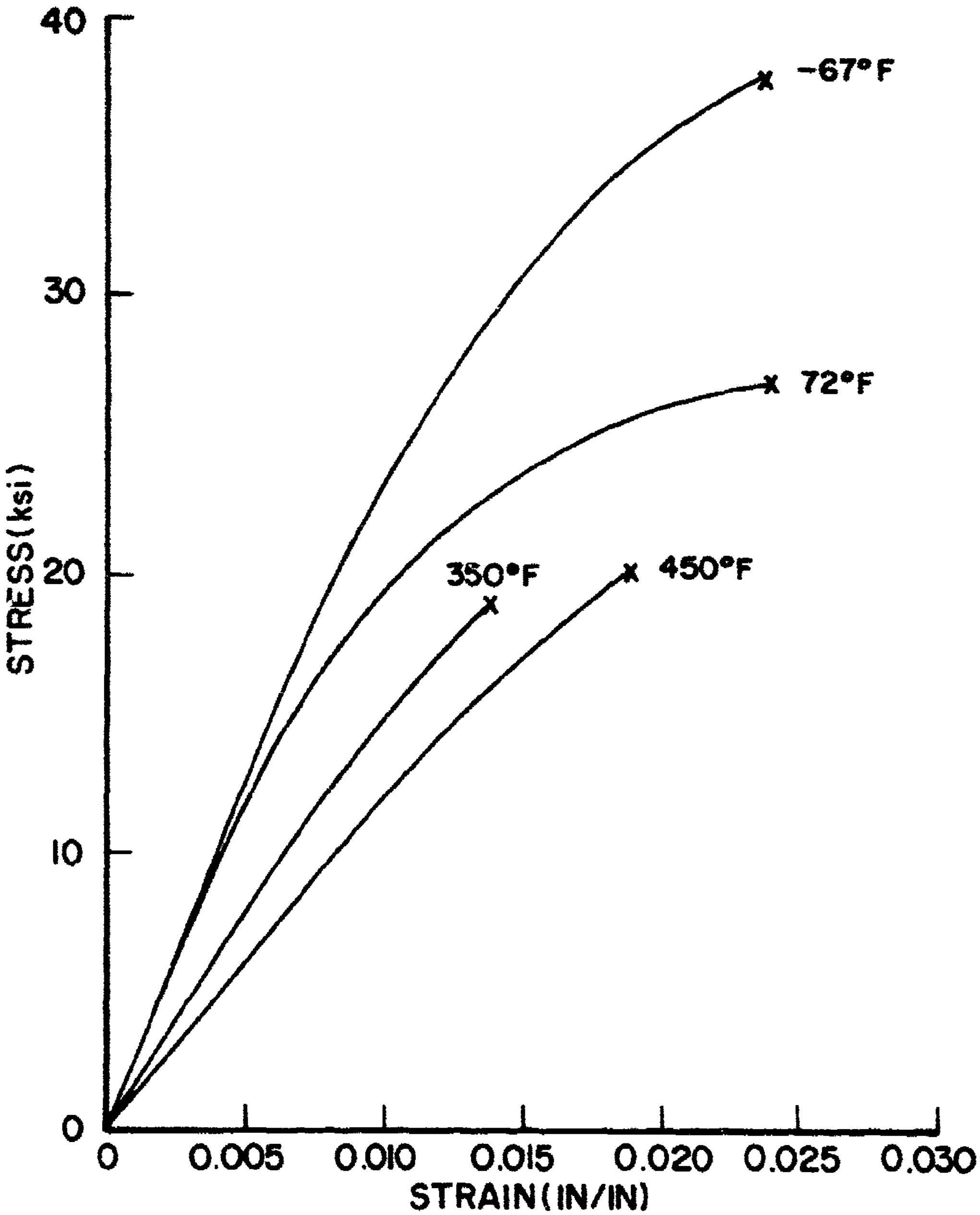


Figure 65. Compressive Stress-Strain Curves for Unidirectional T300/V378A Composite Laminates: 90° Fiber Orientation.

TABLE 53

FLEXURAL PROPERTIES OF T300/V378A COMPOSITE LAMINATES

Composite Material Properties

Material System - T300/V378A	Prepreg by - U.S. Polymeric — Gr/Polyimide
Fiber - T300 Matrix - V378A	Laminate Sp. Gr. - 1.57
Maximum Rated Temperature - 450°F(232°C)	Nominal Ply Thickness - 0.0054 inch (0.14 mm)
Resin Content - 23.2% by wt.	No. of panels from which specimens were tested in this table - 2
Fiber Content - 69.0% by vol.	
Void Content - 2.6% by vol.	
Thickness of each type specimen: 0° - 14 ply ; 90° - 14 ply	

FLEXURE: 0°

	-67°F(-55°C)	72°F(22°C)	350°F(177°C)	450°F(232°C)
F_x^{fu} [ksi](MPa)	[270.7] (1865)[1]	[224.6] (1547)[2]	[170.5] (1175)[3]	[164.1] (1131)[4]
Stnd.Dev. [ksi](MPa)	[15.8] (109)	[5.2] (36)	[6.3] (43)	[9.5] (65)
Range [ksi](MPa)	[248.4-289.4] (1711-1994)	[219.5-232.3] (1512-1601)	[163.4-175.4] (1126-1209)	[156.5-176.1] (1078-1213)
No. of Specimens	5	5	3	5
E_x^f [Msi](GPa)	[16.0] (110)	[17.2] (119)	[15.6] (107)	[16.1] (111)
Stnd.Dev. [Msi](GPa)	[0.7] (5)	[1.2] (8)	[0.6] (4)	[0.6] (4)
No. of Specimens	5	5	3	5
Test Method	3 pt. flexure	4 pt. flexure	3 pt. flexure	3 pt. flexure
Reference	Advanced Composite Design Guide; Jan., 1971[5]			

FLEXURE: 90°

	-67°F(-55°C)	72°F(22°C)	350°F(177°C)	450°F(232°C)
F_y^{fu} [ksi](MPa)	[11.18] (77.0)	[11.58] (79.8)	[8.39] (57.8)	[7.84] (54.0)
Stnd.Dev. [ksi](MPa)	[2.12] (14.6)	[0.91] (6.3)	[1.19] (8.2)	[0.54] (3.7)
Range [ksi](MPa)	[9.40 - 14.38] (64.8 - 99.1)	[10.33 - 12.35] (71.2 - 85.1)	[6.92 - 9.80] (47.7 - 67.5)	[7.07 - 8.52] (48.7 - 58.7)
No. of Specimens	5	5	5	5
E_y^f [Msi](GPa)	[1.82] (12.5)	[1.74] (12.0)	[1.47] (10.1)	[1.29] (8.9)
Stnd.Dev. [Msi](GPa)	[0.11] (0.8)	[0.05] (0.3)	[0.06] (0.4)	[0.09] (0.6)
No. of Specimens	5	5	5	5
Test Method	4 pt. flexure			
Reference	Advanced Composite Design Guide; Jan., 1971[5]			

NOTES:
1. All failures were in tension on lowest ply.
2. Mixed failure mode. Some delamination, some tension on bottom ply, some compressive under upper loading nose.
3. Mixed failure mode. Some tensile failure on bottom ply and some compressive failure on top ply. Two other specimens were tested in 4-point flexure but exhibited shear failures at a flexural stress level of 161.5 ksi (1113 MPa).
4. Two specimens exhibited same mixed failure mode as those tested at 350°F(177°C). Three specimens exhibited only compressive failures on top ply.
5. This procedure corresponds to ASTM D790 except for loading speed and, in the case of the 4-point test, the position of the two upper loading points.

TABLE 54

SHEAR PROPERTIES OF T300/V378A COMPOSITE LAMINATES

Composite Material Properties

Material System - T300/V378A Prepreg by - U.S. Polymeric — Graphite/Polyimide

Fiber - T300 Matrix - V378A

Maximum Rated Temperature - 450°F (232°F)

Laminate Sp. Gr. - 1.59

Resin Content - 26.7% by wt.

Nominal Ply Thickness - 0.0052 inch (0.13 mm)

Fiber Content - 66.3% by vol.

No. of panels from which specimens were tested in this table - 9

Void Content - 0.8% by vol.

Thickness of each type specimen - Inplane - 8 ply ; Interlaminar - 15 ply

INPLANE SHEAR

	-67°F(-55°C)	72°F(22°C)	350°F(177°C)	450°F(232°C)
F^{su}_{xy} [ksi] (MPa)	[10.76] (74.1)	[10.64] (73.3)	[8.06] (55.5)	[7.47] (51.5)
Stnd. Dev. [ksi] (MPa)	[0.59] (4.1)	[0.61] (4.2)	[0.34] (2.3)	[0.17] (1.2)
Range [ksi] (MPa)	[10.17 - 11.56] (70.1 - 79.6)	[9.59 - 11.07] (66.1 - 76.3)	[7.48 - 8.39] (51.5 - 57.8)	[7.23 - 7.70] (49.8 - 53.1)
No. of Specimens	5	5	5	5
G^{s}_{xy} [Msi] (GPa)	[1.86] (12.8)	[1.62] (11.2)	[1.34] (9.2)	[1.15] (7.9)
Stnd. Dev. [Msi] (GPa)	[0.06] (0.4)	[0.05] (0.3)	[0.12] (0.8)	[0.11] (0.8)
No. of Specimens	5	5	5	5
Test Method	±45° Straight-sided tension			
Reference	J. Comp. Mtls. [Vol. 6, p. 252 & Vol. 7, p. 124]			

INTERLAMINAR SHEAR

	-67°F(-55°C)	72°F(22°C)	350°F(177°C)	450°F(232°C)
F^{isu} [ksi] (MPa)	[18.14] (125)	[15.02] (103)	[10.02] (69)	[9.24] (64)
Stnd. Dev. [ksi] (MPa)	[0.63] (4.3)	[0.49] (3.4)	[0.62] (4.3)	[0.17] (1.2)
Range	[17.30-18.88] (119-130)	[14.23-15.56] (98-107)	[9.03-10.75] (62-74)	[8.96-9.43] (62-65)
No. of Specimens	5	10	5	5
Test Method	ASTM D2344			
Reference				

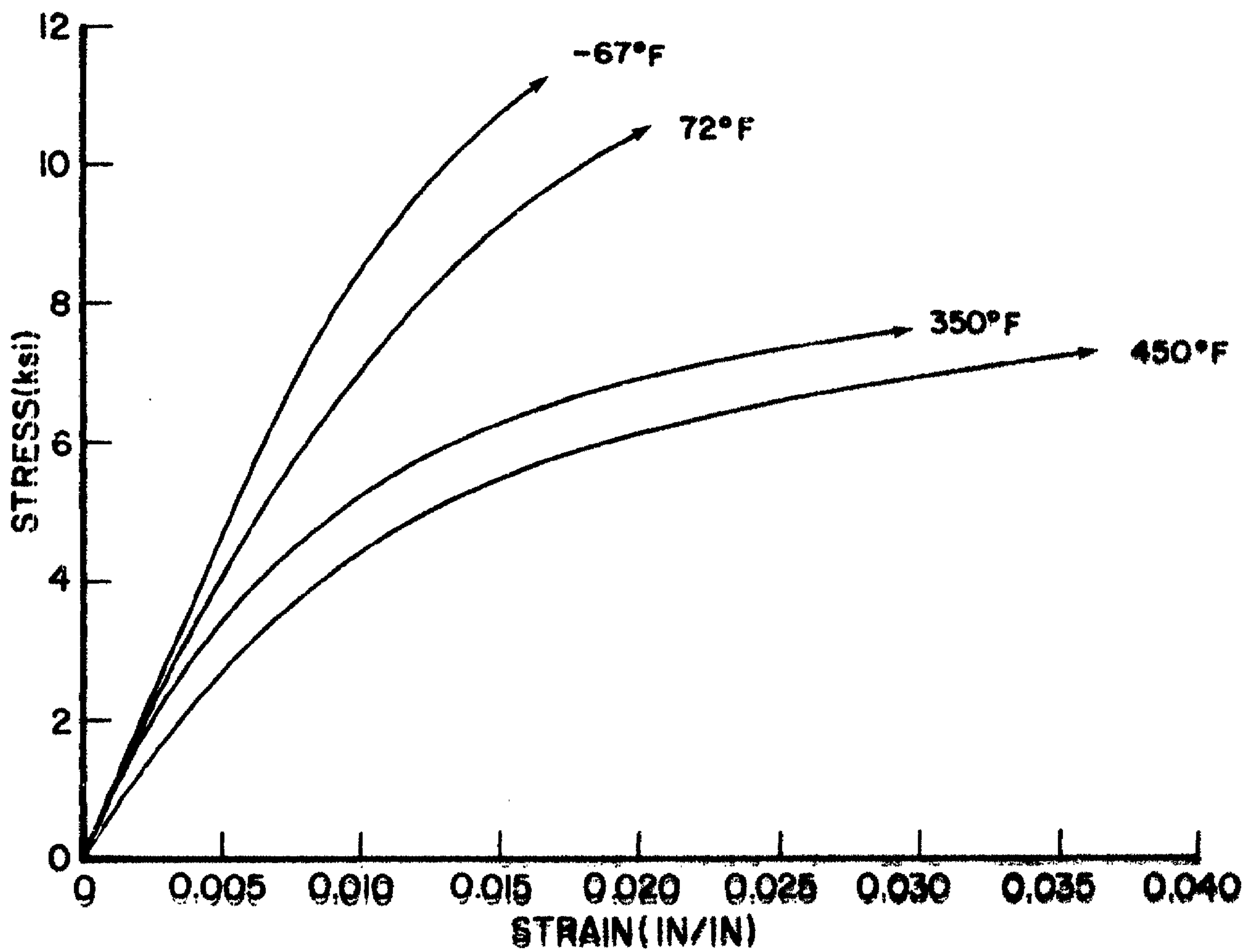


Figure 66. Inplane Shear Stress-Strain Curves for T300/V378A Composite Laminates.

TABLE 55

TENSILE, COMPRESSIVE, AND SHEAR PROPERTIES OF T300/V378A COMPOSITE LAMINATES

Composite Material Properties

Material System - T300/V378A	Prepreg by - U.S. Poly. — Gr/PI
Fiber - T300 Matrix - V378A	Laminate Sp. Gr. - 1.58
Maximum Rated Temperature - 450°F	Nominal Ply Thickness -0.005 inch (0.13mm)
Resin Content - 26.1% by wt.	No. of panels from which specimens were tested in this table - 1
Fiber Content - 66.9% by vol.	Aging Conditions - 160°F & 95-100% R.H.
Void Content - 0.8% by vol.	
Thickness of each type specimen:	Tension -15 ply; Compr. - 20 ply; Shear - 15 ply

TENSION: 90°

	72°F(22°C)	350°F(177°C)	72°F(22°C)	350°F(177°C)
Exposure Time (hrs)	16	18	2588[3]	2588[3]
Wt. Gain(% of orig. dry wt.)	0.78	0.79	1.76	1.73
Stnd. Dev.(%)	0.03	0.04	0.01	0.05
No. of Specimens	5	5	5	5
F_y^{tu} [ksi](MPa)	[5.56](38.3)	[3.87](26.7)	[3.90](26.9)	[0.79](5.4)
Stnd. Dev. [ksi](MPa)	[0.80](5.5)	[0.86](5.9)	[0.24](1.6)	[0.11](0.8)
Range [ksi](MPa)	[4.66-6.60] (32.1-45.4)	[2.62-4.81] (18.1-33.1)	[3.58-4.22] (24.7-29.1)	[0.59-0.86] (4.1-5.9)
No. of Specimens	5	5	5	5
F_y^{tpl} [ksi](MPa)	[4.03](27.8)	[0.94](6.5)	[3.58](24.7)	[0.52](3.6)
Stnd. Dev. [ksi](MPa)	[1.07](7.4)	[0.42](2.9)	[0.21](1.4)	[0.19](1.3)
No. of Specimens	5	5	5	5
E_y^t [Msi](GPa)	[1.31](9.0)	[1.09](7.5)	[1.31](9.0)	[0.94](6.5)
Stnd. Dev. [Msi](GPa)	[0.05](0.3)	[0.08](0.6)	[0.02](0.1)	[0.19](1.3)
No. of Specimens	5	5	5	5
ε_y^{tu} [µin/in](µcm/cm)	4460	3760	2970	840
Stnd. Dev.	1040	710	200	110
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3039			

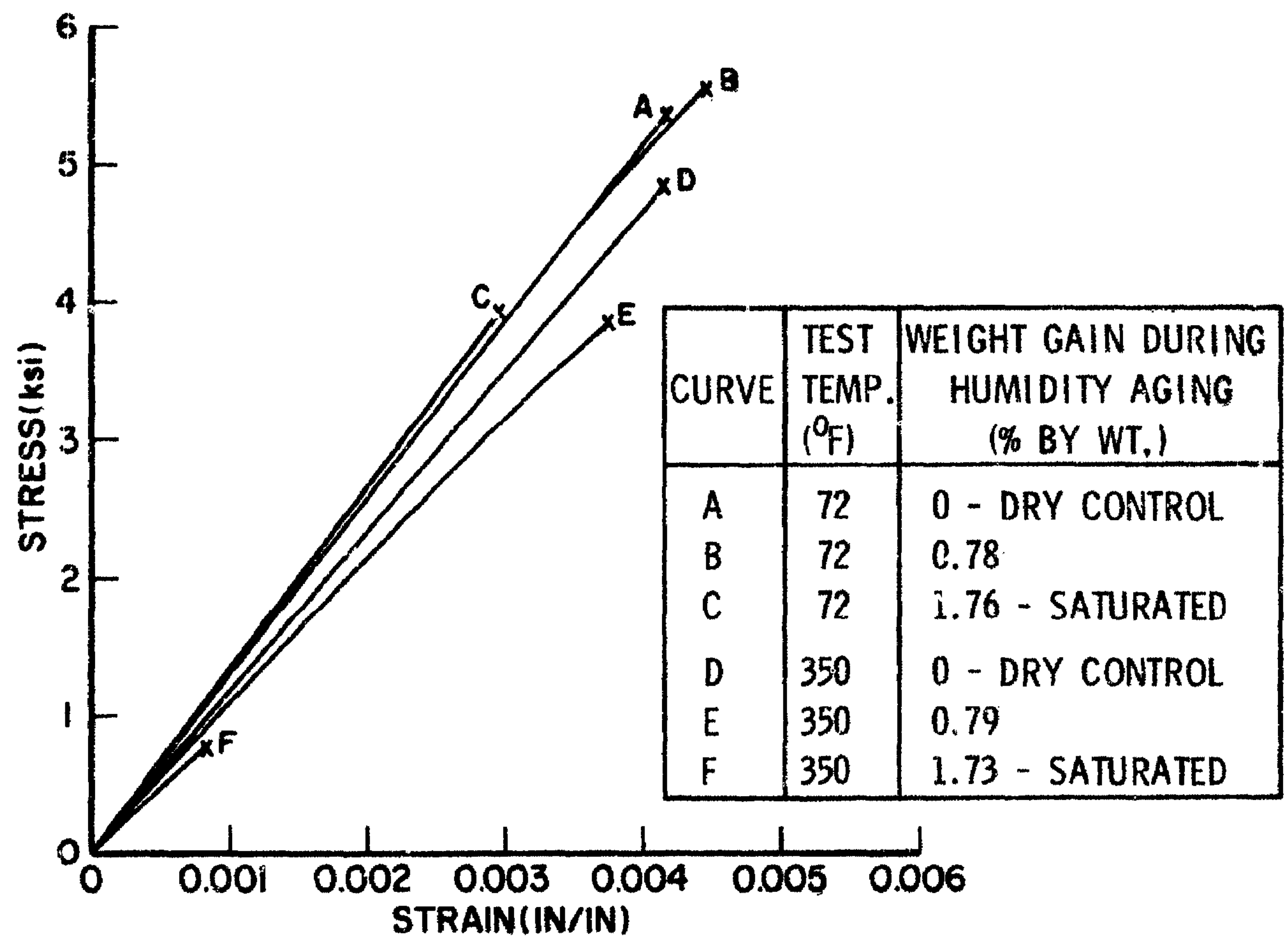
COMPRESSION: 90°

	72°F(22°C)	350°F(177°C)	72°F(22°C)	350°F(177°C)
Exposure Time(hrs)	17.5	17.5	2471[1]	2471[1]
Wt. Gain(% of orig. dry wt.)	0.69	0.71	1.34	1.36
Stnd. Dev. (%)	0.04	0.03	0.01	0.02
No. of Specimens	5	5	5	5
F_y^{cu} [ksi](MPa)	[24.20](167)	[18.33](126)	[25.33](175)	[19.37](133)[4]
Stnd. Dev. [ksi](MPa)	[2.57] (18)	[1.78] (12)	[0.79] (5)	[2.25](15)
Range	[21.17-26.99] (146 - 186)	[16.77-20.41] (116 - 141)	[24.52-26.34] (169 - 181)	[16.93-21.97] (117 - 157)
No. of Specimens	5	5	5	5
F_y^{cpl} [ksi](MPa)	[1.74](12.0)	[2.36](16.3)	[4.33](16.9)	[3.20](22.0)
Stnd. Dev. [ksi](MPa)	[0.18] (1)	[1.68] (12)	[0.97] (7)	[0.80] (6)
No. of Specimens	5	5	5	5
E_y^c [Msi](GPa)	[1.96](13.5)	[1.60](11.0)	[2.45](16.9)	[2.57](17.7)
Stnd. Dev. [Msi](GPa)	[0.38] (3)	[0.41] (3)	[0.45] (3)	[1.09] (8)
No. of Specimens	5	5	5	5
ε_y^{cu} [µin/in](µcm/cm)	31,800	29,600[5]	31,700[5]	25,030[6]
Stnd. Dev.	8,460	---	---	9,010
No. of Specimens	5	2	2	3
Test Method Reference	ASTM D3410			

INTERLAMINAR SHEAR

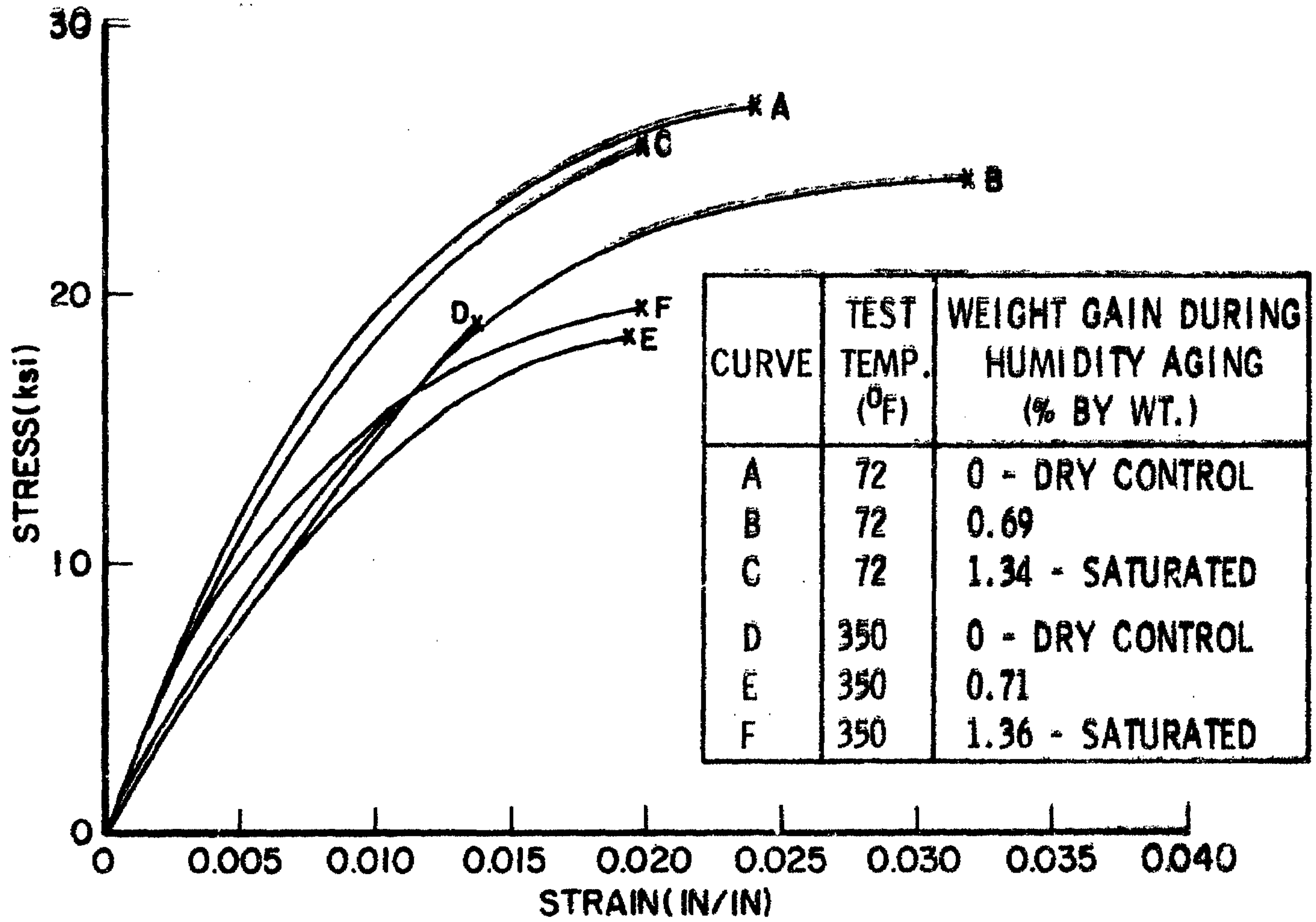
	72°F(22°C)	350°F(177°C)	72°F(22°C)	350°F(177°C)
Exposure Time(hrs)	<48[2]	<48[2]	138	138
Wt. Gain(% of orig. dry wt.)	0.74[2]	0.72[2]	1.20[1]	1.24[1]
Stnd. Dev. (%)	0.12	0.05	0.11	0.13
No. of Specimens	10	5	10	5
F^{isu} [ksi](MPa)	[13.99](96)	[8.91](61)	[14.36](99)	[7.85](54)
Stnd. Dev. [ksi](MPa)	[0.29] (2.0)	[0.76] (5.2)	[0.39] (2.7)	[0.41](2.8)
Range [ksi](MPa)	[13.45-14.40] (93 - 99)	[7.84-9.70] (54 - 67)	[13.59-15.04] (94 - 104)	[7.04-8.14] (49 - 56)
No. of Specimens	5	5	10	5
Test Method Reference	ASTM D2344			

[1] 100% saturation at aging conditions.
[2] Specimens gained weight so rapidly that they were already saturated at first weighing (48 hrs). They were dried in a dessicator at 72°F and 0% R.H. for 116 hrs to reach the weight gain indicated.
[3] Specimens had reached saturation long before this but were kept in humidity cabinet until test schedule permitted testing.
[4] Three specimens tested after five minutes in 350°F oven, giving average strength of 20.95 ksi (144 MPa). Two specimens were tested after 10 minutes in 350°F oven, giving average strength of 17.00 ksi (117 MPa).
[5] Three of the five specimens exhibited evidence of buckling.
[6] Two of the five specimens exhibited evidence of buckling.



CURVE	TEST TEMP. (^{0}F)	WEIGHT GAIN DURING HUMIDITY AGING (% BY WT.)
A	72	0 - DRY CONTROL
B	72	0.78
C	72	1.76 - SATURATED
D	350	0 - DRY CONTROL
E	350	0.79
F	350	1.73 - SATURATED

Figure 67. Tensile Stress-Strain Curves for Unidirectional T300/V378A Composite Laminates After Humidity Aging at 160°F (71°C) and 100% R.H.: 90° Fiber Orientation.



CURVE	TEST TEMP. (^{0}F)	WEIGHT GAIN DURING HUMIDITY AGING (% BY WT.)
A	72	0 - DRY CONTROL
B	72	0.69
C	72	1.34 - SATURATED
D	350	0 - DRY CONTROL
E	350	0.71
F	350	1.36 - SATURATED

Figure 68. Compressive Stress-Strain Curves for Unidirectional T300/V378A Composite Laminates After Humidity Aging at 160°F (71°C) and 100% R.H.: 90° Fiber Orientation.

TABLE 56

CREEP PROPERTIES OF T300/V378A COMPOSITE LAMINATES

Composite Material Properties	
Material System - T300/V378 Prepreg by - U.S. Polymeric	Gr/Polyimide
Fiber - T300 Matrix - V378	Laminate Sp. Gr. - 1.58
Maximum Temperature Rating - 450°F(232°C)	Nominal Ply Thickness - 0.0052 inch(0.13 mm)
Resin Content - 26.0% by wt.	No. of panels from which specimens were tested in this table - 18
Fiber Content - 66.7% by vol.	Thickness of each type specimen:
Void Content - 1.2% by vol.	0/45/90 - 20 ply
Test Method - Straight-sided tension	±45° - 8 ply
Reference - ASTM D2290 and D3039	

CREEP

Temperature		(0,+45,-45,0,0,-45,+45,0,90,0)$_s$	±45°
72°F(22°C)	Stress Level [ksi](MPa)	[101.8] (701)	[16.93] (117)
	Creep Strain, 500 hr(%)	0.0149	0.3575 @ 24 hrs[1]
	No. of Specimens	1	3
	Residual Strength[ksi](MPa)	—	—
	No. of Specimens	1[4]	2
	Stress Level [ksi](MPa)	[95.2] (656)	[14.90] (103)
	Creep Strain, 500 hr(%)	0.0197	0.6011
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	—	—
	No. of Specimens	3	3
	Stress Level [ksi](MPa)	[81.1] (559)	[12.77] (88)
	Creep Strain, 500 hr(%)	0.0162	0.3748
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	—	—
	No. of Specimens	3	2
350°F(177°C)	Stress Level [ksi](MPa)	[84.9] (585)	[12.80] (88)
	Creep Strain, 500 hr(%)	0.0266	1.8756[2]
	No. of Specimens	2	2
	Residual Strength[ksi](MPa)	—	—
	No. of Specimens	2	3
	Stress Level [ksi](MPa)	[74.1] (512)	[11.28] (78)
	Creep Strain, 500 hr(%)	0.0140	0.9706[2]
	No. of Specimens	3	2
	Residual Strength[ksi](MPa)	—	—
	No. of Specimens	3	3
	Stress Level [ksi](MPa)		[9.67] (67)
	Creep Strain, 500 hr(%)		0.7073[2]
	No. of Specimens		2
	Residual Strength[ksi](MPa)		—
	No. of Specimens		3
450°F(232°C)	Stress Level [ksi](MPa)		[11.95] (82)
	Creep Strain, 500 hr(%)		—[3]
	No. of Specimens		—
	Residual Strength[ksi](MPa)		—
	No. of Specimens		—
	Stress Level [ksi](MPa)		[10.45] (72)
	Creep Strain, 500 hr(%)		0.6713[5]
	No. of Specimens		1
	Residual Strength[ksi](MPa)		—
	No. of Specimens		3
	Stress Level [ksi](MPa)		
	Creep Strain, 500 hr(%)		
	No. of Specimens		
	Residual Strength[ksi](MPa)		
	No. of Specimens		

[1] Strain gage failed on one specimen after 24 hrs., on another after 144 hrs. One specimen failed during test.

[2] Strain gage failed on one specimen during test.

[3] Strain gage failed on three specimens during test.

[4] Two specimens failed on loading.

[5] Strain gage failed on two specimens during test.

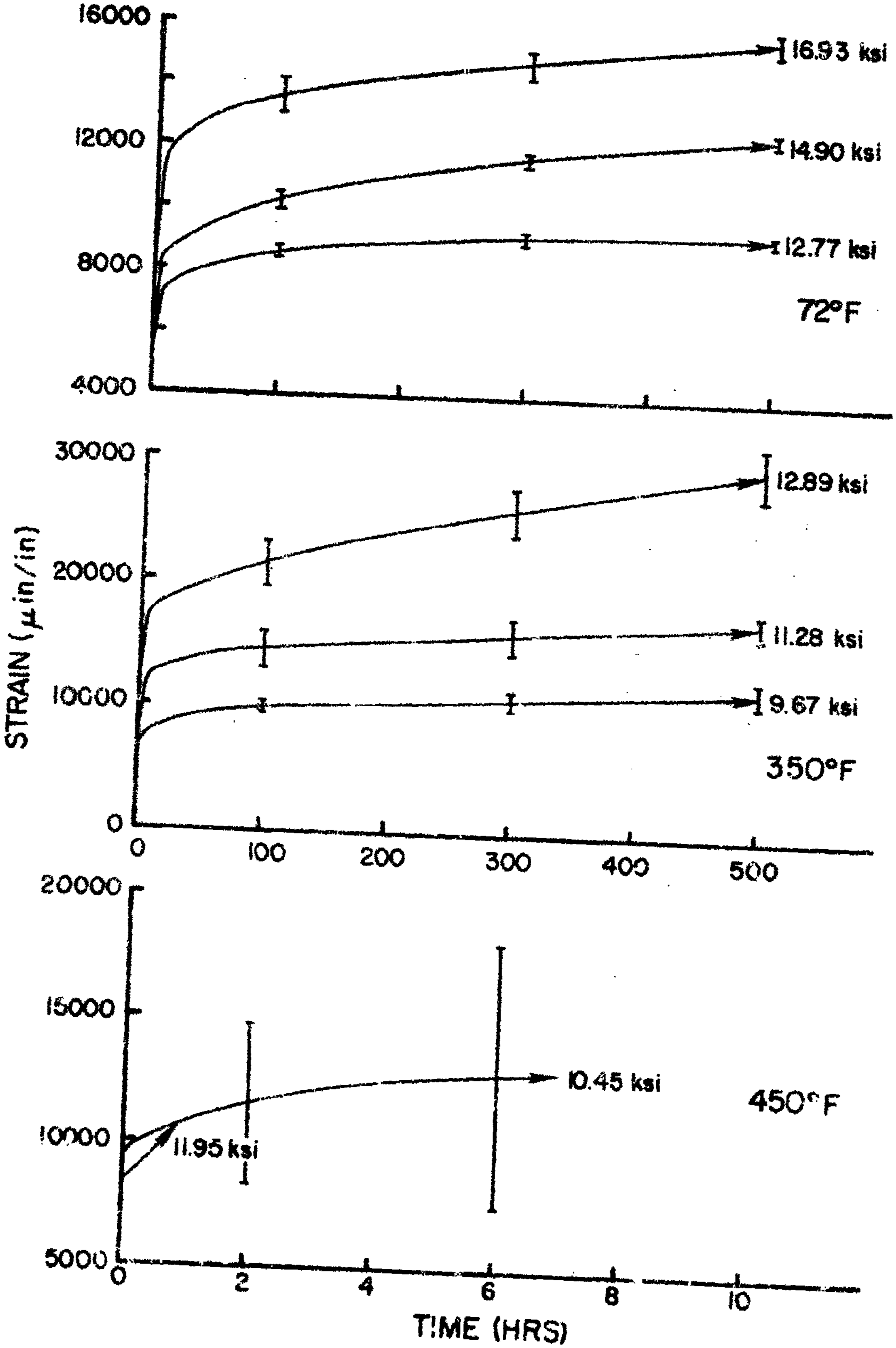


Figure 69. Tensile-Creep Behavior of Bidirectional T300/V378A Composite Laminates: $\pm 45°$ Fiber Orientation.

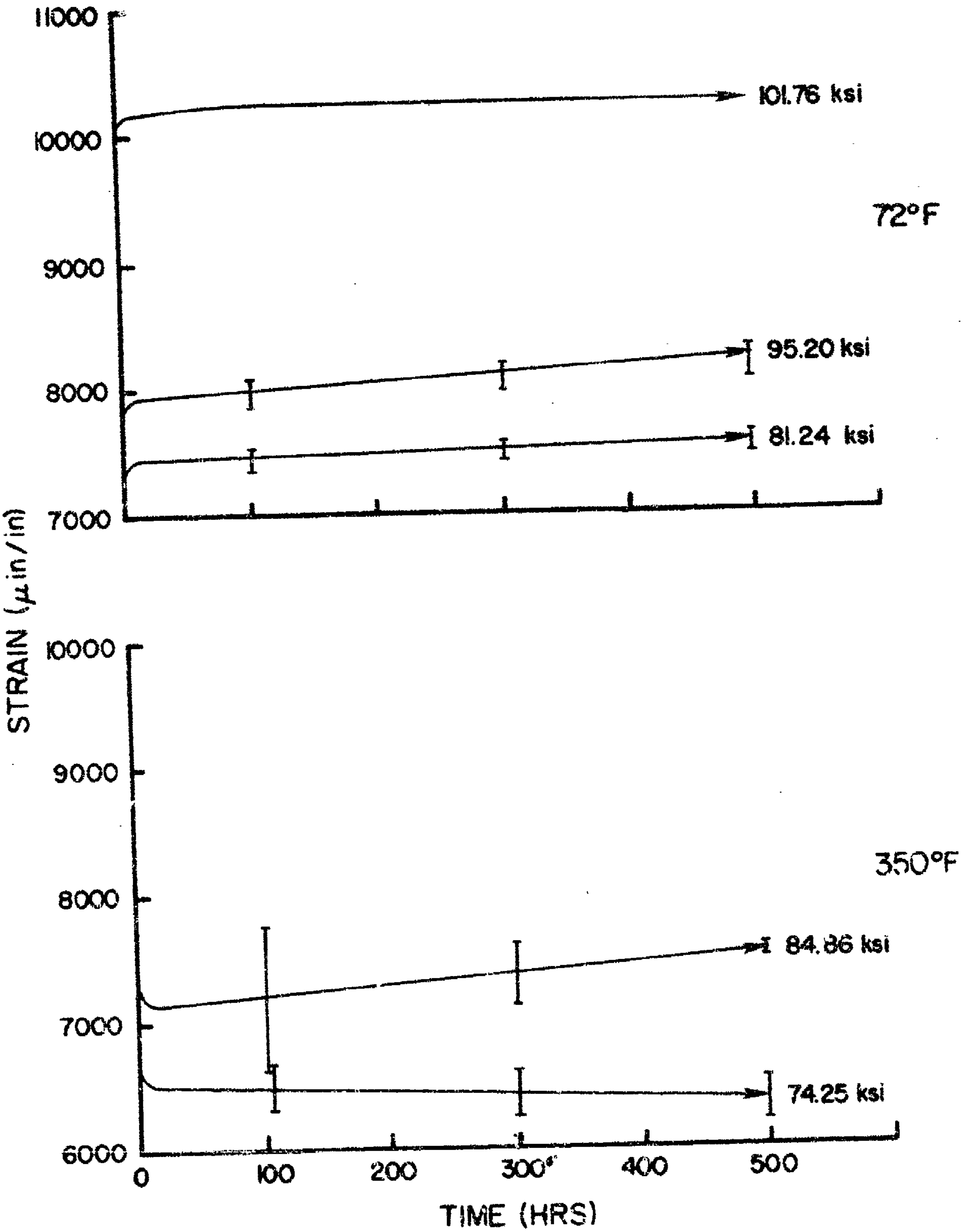


Figure 70. Tensile-Creep Behavior of T300/V378A Composite Laminates: $(0,+45,-45,0,0,-45,+45,0,90,0)_s$ Fiber Orientation.

TABLE 57

STRESS RUPTURE PROPERTIES OF T300/V378A COMPOSITE LAMINATES

Composite Material Properties	
Material System - T300/V378A	Gr/Polyimide
Fiber - T300 Matrix - V378A	
Maximum Temperature Rating - 450°F	Prepreg by - U.S. Polymeric
Resin Content - 26.0% by wt.	Laminate Sp. Gr. - 1.58
Fiber Content - 66.8% by vol.	Nominal Ply Thickness - 0.0052 inch (0.13 mm)
Void Content - 1.2% by vol.	No. of panels from which specimens were tested in this table - 16
Test Method - Straight-sided tension	Thickness of each type specimen:
Reference - ASTM D2290 and D3039	(0/±45/90) - 20 ply
	±45 - 8 ply

STRESS RUPTURE

Temperature	Fiber Orientation	$(0,+45,-45,0,0,-45,+45,0,90,0)_s$	±45°
72°F (22°C)	Stress Level[ksi] (MPa)	[101.8] (701)	[16.93] (117
	Time to Failure(hrs)	176[1]	363[2]
	No. of Specimens	3	3
	Residual Strength(ksi] (MPa)	—	—
	No. of Specimens	1	2
	Stress Level[ksi] (MPa)	[95.2] (656)	[14.90] (103)
	Time to Failure(hrs)	503+[4]	581+[3]
	No. of Specimens	3	3
	Residual Strength[ksi] (MPa)	—	—
	No. of Specimens	3	3
260°F (127°C)	Stress Level[ksi] (MPa)	[84.9] (585)	[12.89] (89)
	Time to Failure(hrs)	532+[2]	502+[3]
	No. of Specimens	2	3
	Residual Strength[ksi] (MPa)	—	—
	No. of Specimens	2	3
	Stress Level[ksi] (MPa)	[74.3] (512)	[11.28] (78)
	Time to Failure(hrs)	507+[3]	527+[3]
	No. of Specimens	3	3
	Residual Strength[ksi] (MPa)	—	—
	No. of Specimens	3	3
350°F (177°C)	Stress Level[ksi] (MPa)		[11.95] (82)
	Time to Failure(hrs)		230
	No. of Specimens		3[2]
	Residual Strength[ksi] (MPa)		—
	No. of Specimens		1
	Stress Level[ksi] (MPa)		[10.45] (72)
	Time to Failure(hrs)		503+[3]
	No. of Specimens		3
	Residual Strength[ksi] (MPa)		—
	No. of Specimens		3

[1]One specimen survived for 500 hours without failure.
[2]Two specimens survived for 500 hours without failure.
[3]Three specimens survived for 500 hours without failure.

TABLE 58

FATIGUE PROPERTIES OF T300/V378A COMPOSITE LAMINATES

Composite Material Properties

Material System - T300/V378A
Prepreg by - U.S. Polymeric
Gr/Polyimide
Fiber - T300 Matrix - V378A
Maximum Temperature Rating - 450°F (232°C)
Resin Content - 25.8% by wt.
Fiber Content - 66.7% by vol.
Void Content - 1.5% by vol.
Laminate Sp. Gr. - 1.57
Nominal Ply Thickness - 0.0052 inch (0.13 mm)
No. of panels from which specimens were tested in this table - 15
Thickness of each type specimen:
±45 - 8 ply
0/±45/90 - 20 ply
Test Method - Straight-sided tension
Reference - ASTM D3039

TENSILE FATIGUE, R=0.1 [3]

Temperature	Fiber Orientation	±45°	0/±45/90 [1]	0/±45/90 [1,2]
72°F (22°C)	Max. Stress [ksi] (MPa)	[15.97] (110)	[95.8] (660)	
	Lifetime (cycles)	16,742	15,534	
	No. of Specimens	5	5	
	Residual Strength [ksi] (MPa)	---	---	
	No. of Specimens	0	0	
	Max. Stress [ksi] (MPa)	[14.90] (103)	[92.8] (639)	[83.8] (577)
	Lifetime (cycles)	68,856	255,077+ [4,5]	61,300
	No. of Specimens	4	4	1
	Residual Strength [ksi] (MPa)	---	---	---
	No. of Specimens	0	1	0
	Max. Stress [ksi] (MPa)	[13.84] (95)	[89.8] (619)	[79.1] (545)
	Lifetime (cycles)	429,359	1,579,910+ [4]	467,807
	No. of Specimens	5	4	4
	Residual Strength [ksi] (MPa)	---	---	---
	No. of Specimens	0	1	0
350°F (177°C)	Max. Stress [ksi] (MPa)	[13.70] (94)	[90.1] (621)	
	Lifetime (cycles)	4,727	96,587	
	No. of Specimens	5	5	
	Residual Strength [ksi] (MPa)	---	---	
	No. of Specimens	0	0	
	Max. Stress [ksi] (MPa)	[12.90] (89)	[87.5] (603)	
	Lifetime (cycles)	52,012	323,176+ [6]	
	No. of Specimens	4	3	
	Residual Strength [ksi] (MPa)	---	---	
	No. of Specimens	0	0	
	Max. Stress [ksi] (MPa)	[12.09] (83)	[84.8] (584)	
	Lifetime (cycles)	347,393	531,563	
	No. of Specimens	5	5	
	Residual Strength [ksi] (MPa)	---	---	
	No. of Specimens	0	0	

1. Stacking sequence $(0,+45,-45,0,0,-45,+45,0,90,0)_s$.
2. These specimens had a 0.1935 inch (0.491 cm) hole in the center of the test section. Stresses calculated using net cross-sectional area.
3. Fatigue lifetimes are log mean values. All residual strengths determined by tensile test at 72°F (22°C).
4. One specimen ran out to 10^7 cycles without failure.
5. One specimen broke at 1,269,500 cycles due to power outage.
6. One specimen failed at 2,128,300 cycles due to oven overheating.

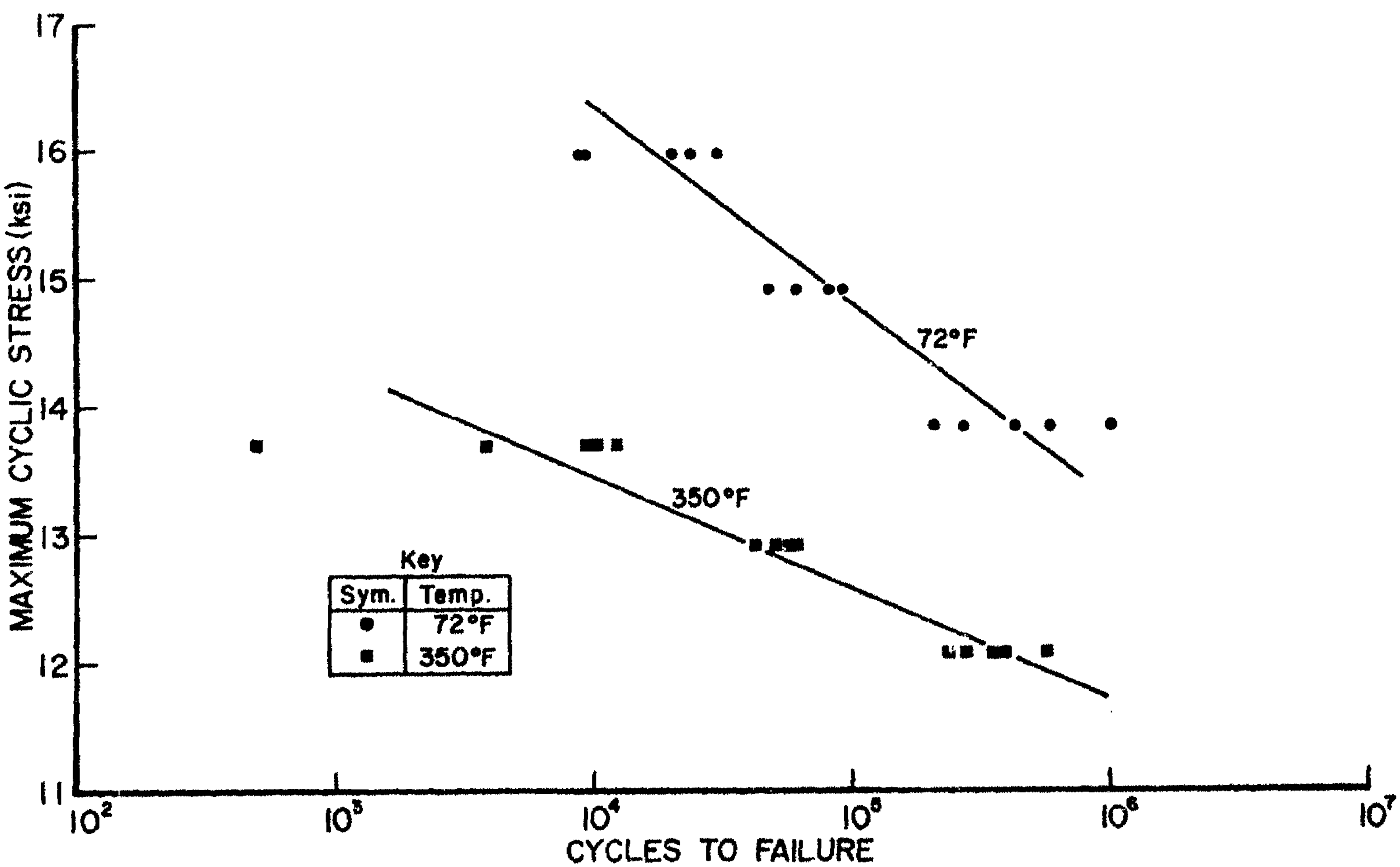


Figure 71. Tensile-Tensile Fatigue Behavior of T300/V378A Composite Laminates: ±45° Fiber Orientation, R = 0.10, 10 Hz.

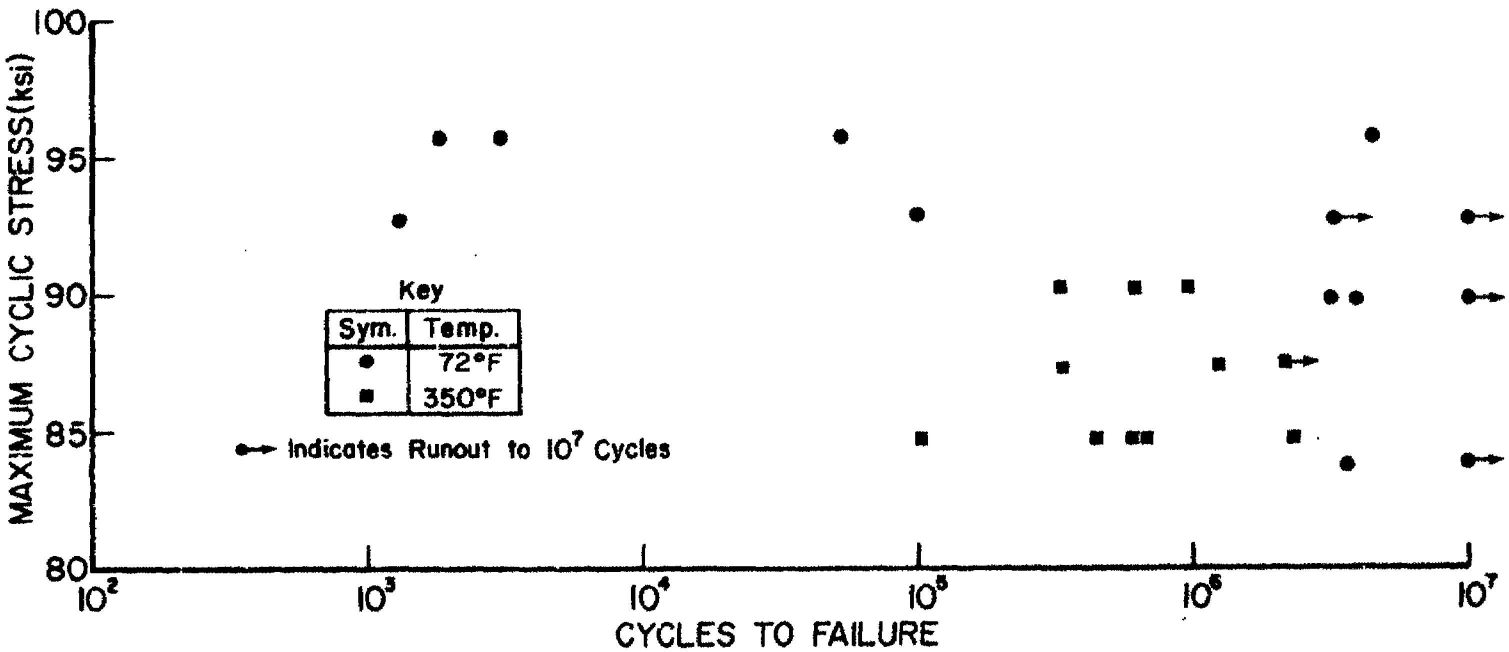


Figure 72. Tensile-Tensile Fatigue Behavior of T300/V378A Composite Laminates: $(0,45,-45,0,0,-45,45,0,90,0)_s$ Fiber Orientation, R = 0.10, 10 Hz.

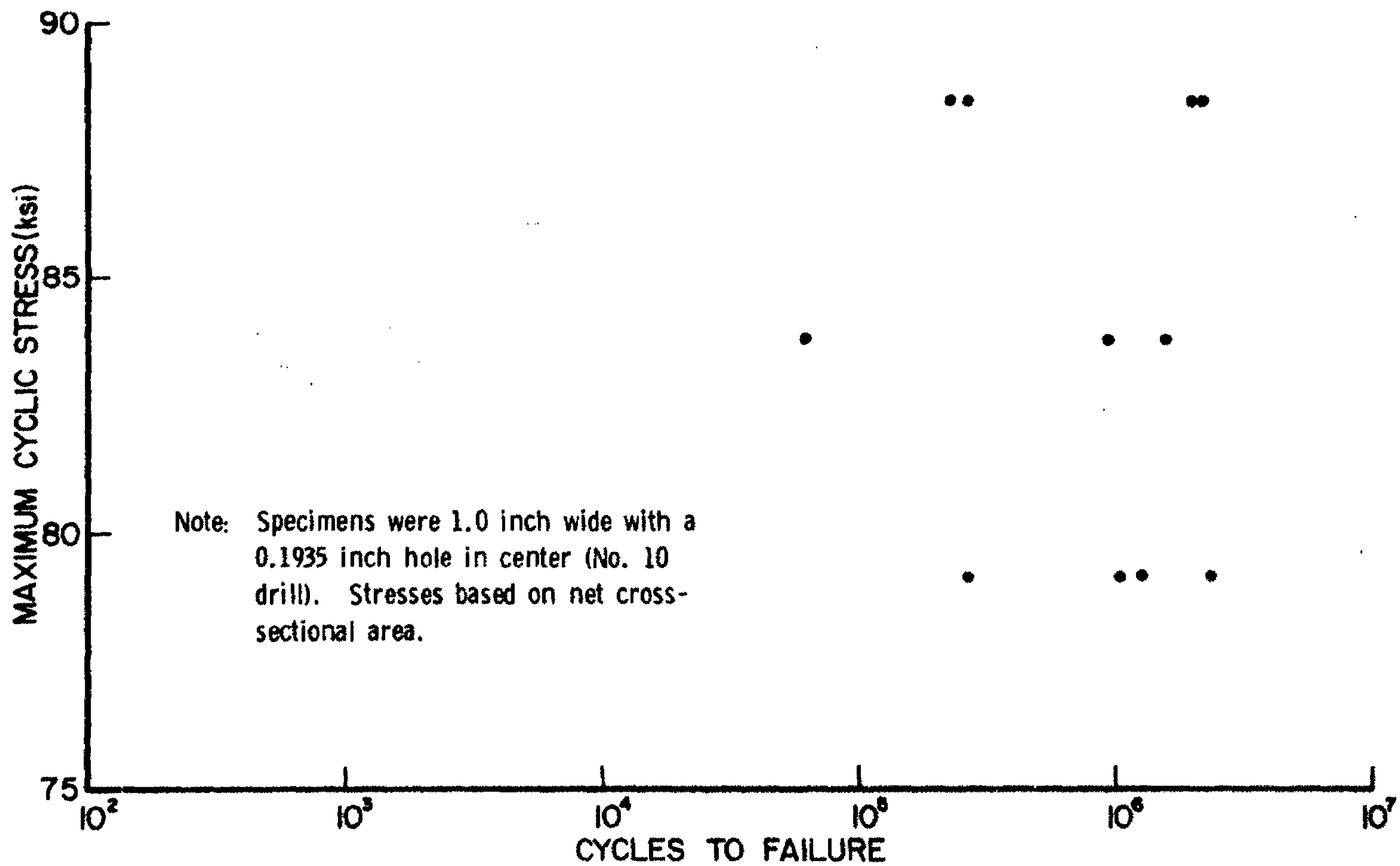


Figure 73. Tensile-Tensile Fatigue Behavior of T300/V378A Composite Laminates: $(0,45,-45,0,0,-45,45,0,90,0)_s$ Fiber Orientation, R = 0.10, 10 Hz.

TABLE 59

THERMOPHYSICAL PROPERTIES OF T300/V378A COMPOSITE LAMINATES

Composite Material Properties

Material System - T300/V378A Fiber - T300 Matrix - V378A Maximum Temperature Rating - 450°F(232°C) Resin Content - 24.6% by wt. Fiber Content - 67.2% by vol. Void Content - 2.0% by vol.	Prepreg by - U.S. Poly. — Gr/PI Laminate Sp. Gr. - 1.57 Average Ply Thickness - 0.0051 inch(0.13 mm) No. of panels from which specimens were tested in this table - 2
Thickness of each type specimen: Therm. Exp. - 40 ply; Therm. Cond. - 40 ply	Spec. Ht. - 1 ply; Glass Trans. - 8 ply

THERMOPHYSICAL PROPERTIES: 0°

	-67°F(-55°C)	72°F(22°C)	350°F(177°C)	450°F(232°C)	Test Method
Thermal Expansion[1]					
α_x[μin/in-°F](μcm/cm-°C)	[0.12](0.22)	[-0.15](-0.27	[-0.11](-0.20	[-0.14](-0.25)	TMA[2]
α_y[μin/in-°F](μcm/cm-°C)	[15.8](28.4)	[17.3] (31.2)	[22.8](41.1)	[23.7](42.7)	
No. of Specimens per direction	3	3	3	3	
Specific Heat					
C_p[btu/lb.-°F](J/kg-°C)	[0.123](515)	[0.206](862)	[0.748](3132)	[0.761](3186	DSC[3]
No. of Specimens	3	3	3	3	
Thermal Conductivity[1]					
k_z[btu-ft/ft^2-hr-°F]	[0.28]	[0.34]	[0.44]	[0.47]	
(W/m-°C)	(0.50)	(0.59)	(0.77)	(0.83)	
No. of Specimens	3	3	3	3	
Glass Transition Temp.					
Dry [°F](°C)	[702] (372)				
Wet [°F](°C)	[702] (372)[5]				DMA[4]

THERMOPHYSICAL PROPERTIES: ±45°

	-67°F(-55°C)	72°F(22°C)	350°F(177°C)	450°F(232°C)	Test Method
Thermal Expansion[1]					
α_x[μin/in-°F](μcm/cm-°C)	[2.21](3.98)	[1.65](2.97)	[2.11](3.79)	[2.06](3.71)	TMA[2]
No. of Specimens per direction	3	3	3	3	
Thermal Conductivity[1]					
k_z[btu-ft/ft^2-hr-°F]	[0.25]	[0.29]	[0.39]	[0.42]	Comparative
(W/m-°C)	(0.44)	(0.51)	(0.67)	(0.72)	
No. of Specimens	3	3	3	3	

NOTES: 1. On the unidirectionally reinforced specimens, the x-direction is along the fiber axis, the y-direction is across the fiber axis, and the z-direction is through the thickness (identical to the y-direction). On ±45° bidirectionally reinforced specimens, the x and y directions are identical and oriented at 45° to either fiber direction, while the z-direction is through the thickness.

2. Thermo-Mechanical Analysis

3. Differential Scanning Calorimetry

4. Dynamic Mechanical Analysis

5. Gained wt. very rapidly. May have dried very rapidly also, so actual value was for dry material by end of test.

4.5 HyE 1076J

This system consists of 15,000 filament tow Thornel 300 from Union Carbide in Fiberite's 976 epoxy resin matrix.

Tables 60 through 74 present the data generated for this 350°F (177°C) graphite/epoxy composite material. Figures 74 through 89 illustrate the stress-strain, fatigue, and creep behavior of this material as well as the effects of humidity aging upon selected composite materials.

The 976 resin system was developed to retain higher property levels after humidity aging than earlier 350°F (177°C) epoxy systems. Two tables released by Fiberite are included at the end of this section which provides comparisons of the 934 and 976 systems.

TABLE 60

PROCESSING CONDITIONS FOR HyE 1076J
COMPOSITE LAMINATES

Composite Processing Information	
Material System - HyE 1076J Fiber - T300/15K Matrix - 976 Maximum Rated Temperature - 350°F(177°C)	Gr/Ep Prepreg by - Fiberite

Laminate Processing Schedule

Layup Procedure: The prepreg was stored in a closed wrapper at 0°F (-18°C). Prepreg was warmed to room temperature before removal from wrapper to prevent moisture condensation on prepreg. Plies were cut to desired size with razor knife and stacked in desired sequence (release paper removed from each ply). The stack was placed in the autoclave according to the layup system illustrated in Figure 74. The corprene edge dam serves to restrict fiber flow.

Cure Schedule: Apply full vacuum and hold for 1/2 hour at room temperature. Heat to 250°F (121°C) at a rate of 2-5°F/min. When temperature has reached 250°F (121°C) apply 100 psi above bladder (while retaining vacuum). Hold at 250°F (121°C) for 45 minutes then heat to 350°F (177°C) at a rate of 2-5°F/min. Hold at 350°F (177°C) for 2 hours then cool to 150°F (66°C) at 2-5°F/min. Release pressure when temperature has reached 150°F (66°C), then release vacuum and remove panel from autoclave.

Postcure Schedule: None.

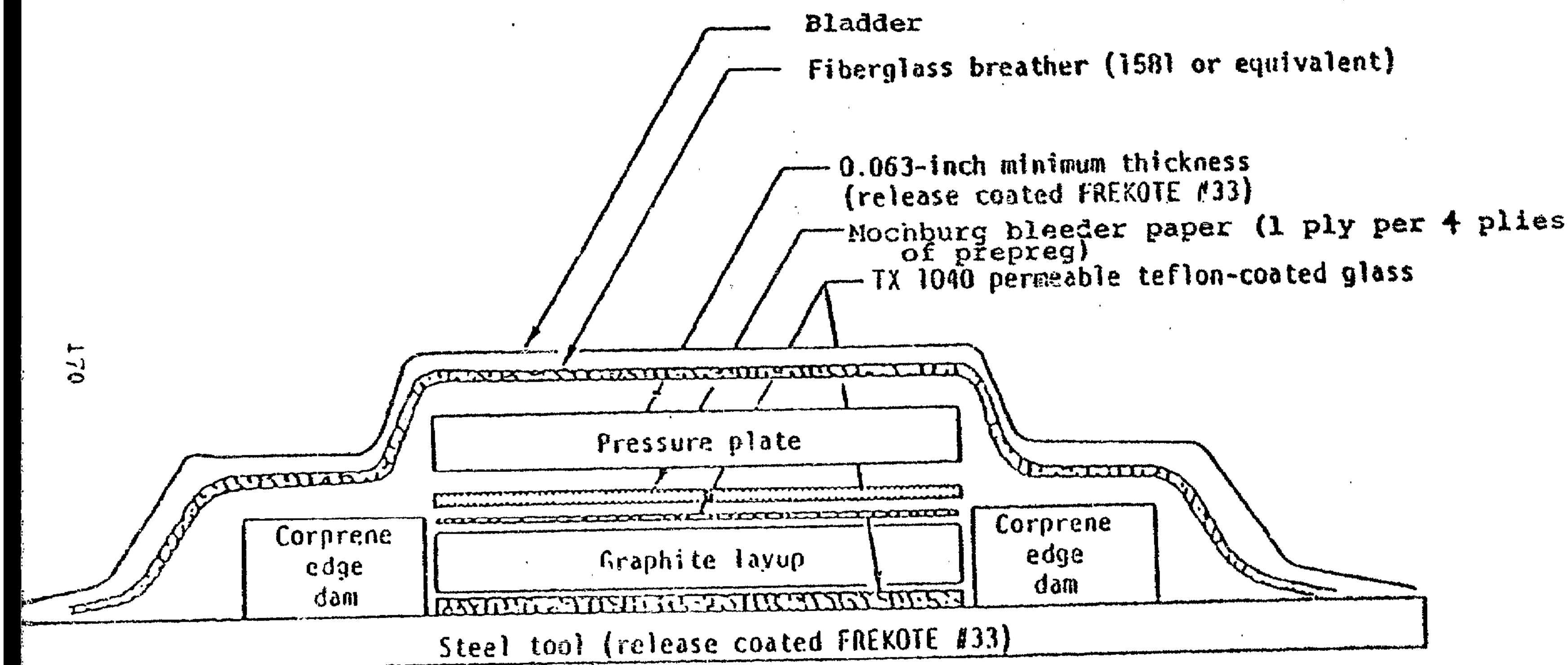


Figure 74. Layup System for HyE 1076J Laminates.

TABLE 61

PREPREG AND COMPOSITE PHYSICAL PROPERTIES

Composite Physical Property Information

Material System - HyE 1076J Fiber - T300/15K Matrix - 976 Maximum Rated Temperature - 350°F(177°C)	Gr/Ep Prepreg by - Fiberite

Prepreg Physical Properties

(Property)	(Stnd.Dev.)	(Range)	(Test Method)	(Ref.)
Volatile Content- 0.44% by wt.		0.23-0.57	QCI-C-V-14	Fiberite
Resin Content- 37.7% by wt.		37.5-37.8	R-15	Fiberite
Gel Time - 21.3 minutes		20.1-22.3	G2	Fiberite
No. of Rolls Involved- 1				
No. of Batches Involved- 1				

Laminate Physical Properties[1]

	(Stnd.Dev.)	(Range)	(Test Method)	(Ref.)
No. of Panels- 34				
Fiber Content- 68.0% by vol.	1.5%	62.3-69.9%	Acid Digestion	
Resin Content- 25.6% by wt.	2.6%	23.8-37.7%	AFML-TR-67-243	
Void Content- ≐ 0% by vol.			D2734	ASTM
Laminate Sp. Gr.- 1.62			D792	ASTM
Fiber Sp. Gr.- 1.78	As reported by manufacturer.			
Matrix Sp. Gr.- 1.28	As reported by manufacturer.			
Thickness per ply-			---	---

[1]The properties reported here represent averages for all panels of this material used throughout the program.

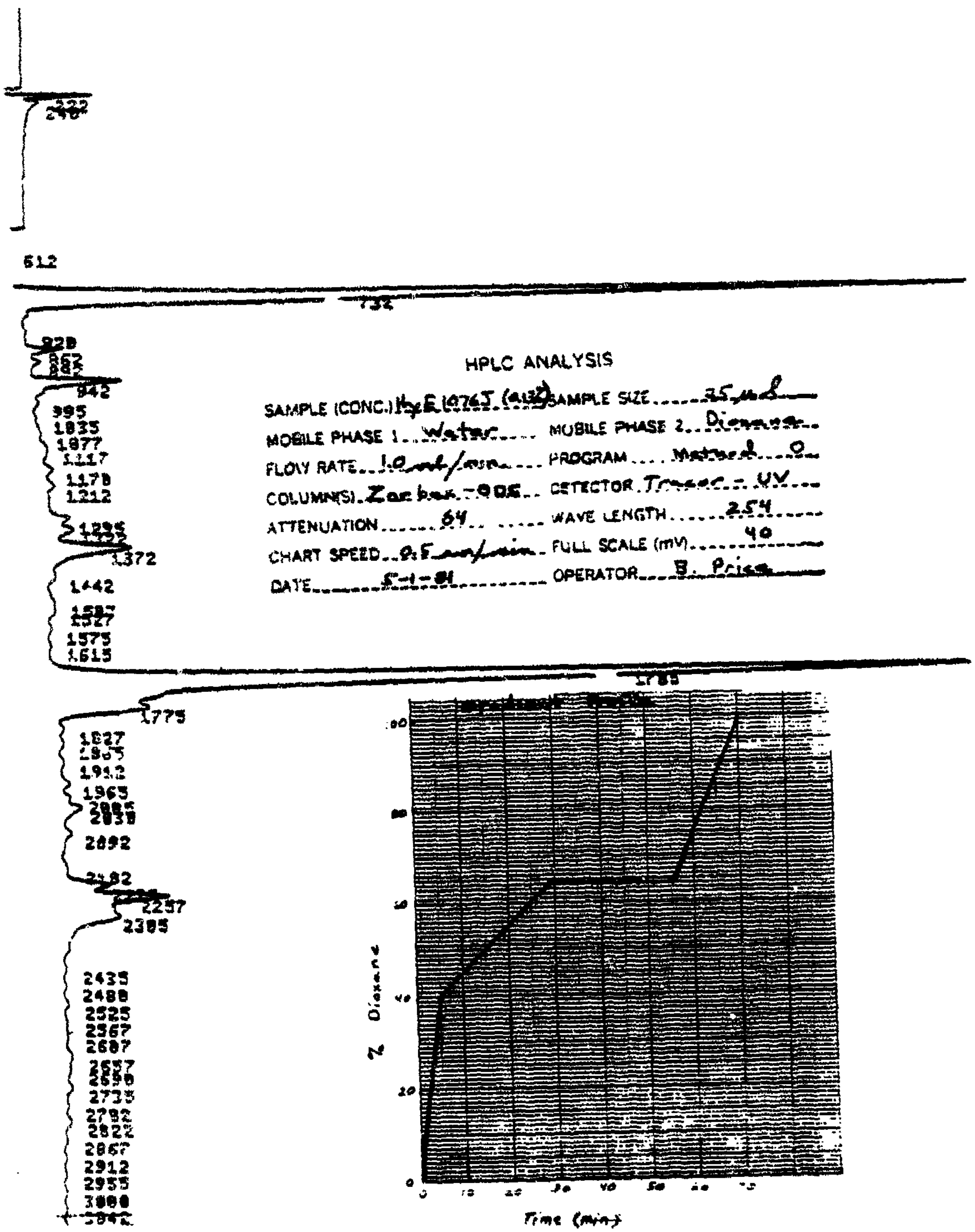


Figure 75. HPLC Analysis of HyE 1076J.

TABLE 62

TENSILE PROPERTIES OF HyE 1076J COMPOSITE LAMINATES

Composite Material Properties

Material System - HyE 1076J
Fiber - T300/15K   Matrix - 976
Maximum Rated Temperature - 350°F(177°C)
Resin Content - 35.3%/0; 24.5%/90 by wt.
Fiber Content - 58.6%/0; 69.4%/90 by vol.
Void Content - ≈ 0
Thickness of each type specimen: 0° - 6 ply ; 90° - 15 ply

Prepreg by - Fiberite
Laminate Sp. Gr. - 1.60/0; 1.64/90
Nominal Ply Thickness-0.0053 in./0;0.0049 in./90
No. of panels from which specimens were tested in this table - 7

Gr/Ep

TENSION: 0°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{tu} [ksi](MPa)	[196.8] (1356)	[207.1] (1427)	[232.3] (1601)	[228.4] (1573)
Stnd.Dev. [ksi](MPa)	[15.1] (104)	[13.4] (92)	[15.9] (110)	[8.6] (59)
Range [ksi](MPa)	[172.5 - 213.5] (1189 - 1471)	[190.8 - 219.4] (1315 - 1512)	[211.5 - 254.7] (1457 - 1755)	[218.7 - 242.2] (1507 - 1669)
No. of Specimens	5	5	5	5
F_x^{tpl} [ksi](MPa)	[196.8] (1356)	[207.1] (1427)	[232.3] (1601)	[228.4] (1573)
Stnd.Dev. [ksi](MPa)	[15.1] (104)	[13.4] (92)	[15.9] (110)	[8.6] (59)
No. of Specimens	5	5	5	5
E_x^{t} [Msi](GPa)	[20.4] (141)	[19.3] (133)	[22.4] (154)	[22.1] (152)
Stnd.Dev. [Msi](GPa)	[0.5] (3)	[1.0] (7)	[0.5] (3)	[1.4] (10)
No. of Specimens	5	5	5	5
ε_x^{tu} [µin/in](µcm/cm)	8,600	10,420	9,900	9,930
Stnd.Dev.	450	360	440	530
No. of Specimens	3	5	5	4
ν_{xy}^{t}	0.32	0.32	0.31	0.35
Stnd. Dev.	0.02	0.02	0.03	0.03
No. of Specimens	5	5	5	5
Test Method Reference	Straight-sided tension ASTM D3039			

TENSION: 90°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_y^{tu} [ksi](MPa)	[4.73] (33)	[5.66] (39)	[3.81] (26)	[3.47] (24)
Stnd.Dev. [ksi](MPa)	[1.19] (8)	[0.87] (6)	[0.66] (5)	[0.46] (3)
Range	[3.23 - 6.29] (22 - 43)	[4.53 - 6.52] (31 - 45)	[2.87 - 4.68] (20 - 32)	[2.67 - 3.83] (18 - 26)
No. of Specimens	5	5	5	5
F_y^{tpl} [ksi](MPa)	[4.73] (154)	[5.66] (39)	[3.81] (26)	[3.47] (24)
Stnd.Dev. [ksi](MPa)	[1.19] (8)	[0.87] (6)	[0.66] (5)	[0.46] (3)
No. of Specimens	5	5	5	5
E_y^{t} [Msi](GPa)	[1.69] (12)	[1.34] (9)	[1.37] (9)	[1.30] (9)
Stnd.Dev. [Msi](GPa)	[0.2] (1)	[0.04] (0.3)	[0.1] (1)	[0.08] (0.6)
No. of Specimens	5	5	5	5
ε_y^{tu} [µin/in](µcm/cm)	2,760	3,900	2,640	2,620
Stnd. Dev.	560	570	500	350
No. of Specimens	5	5	5	5
ν_{yx}^{t}	0.026[1]	0.022[1]	0.019[1]	0.020[1]
Stnd. Dev.	---	---	---	---
No. of Specimens	---	---	---	---
Test Method Reference	Straight-sided tension ASTM D3039			

[1]Computed using elastic modulii and longitudinal Poisson's ratio.

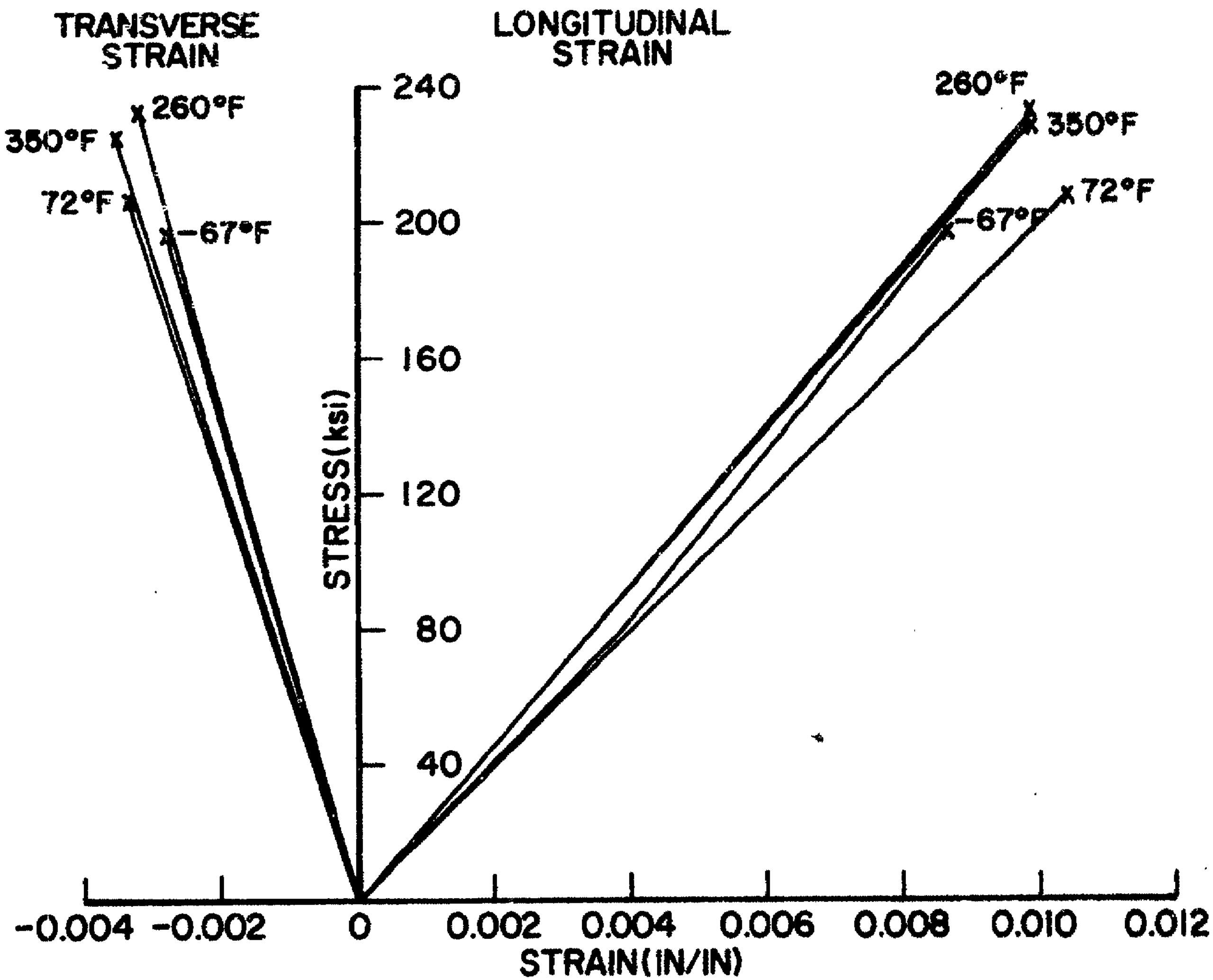


Figure 76. Tensile Stress-Strain Curves for Unidirectional HyE 1076J Composite Laminates: 0° Fiber Orientation.

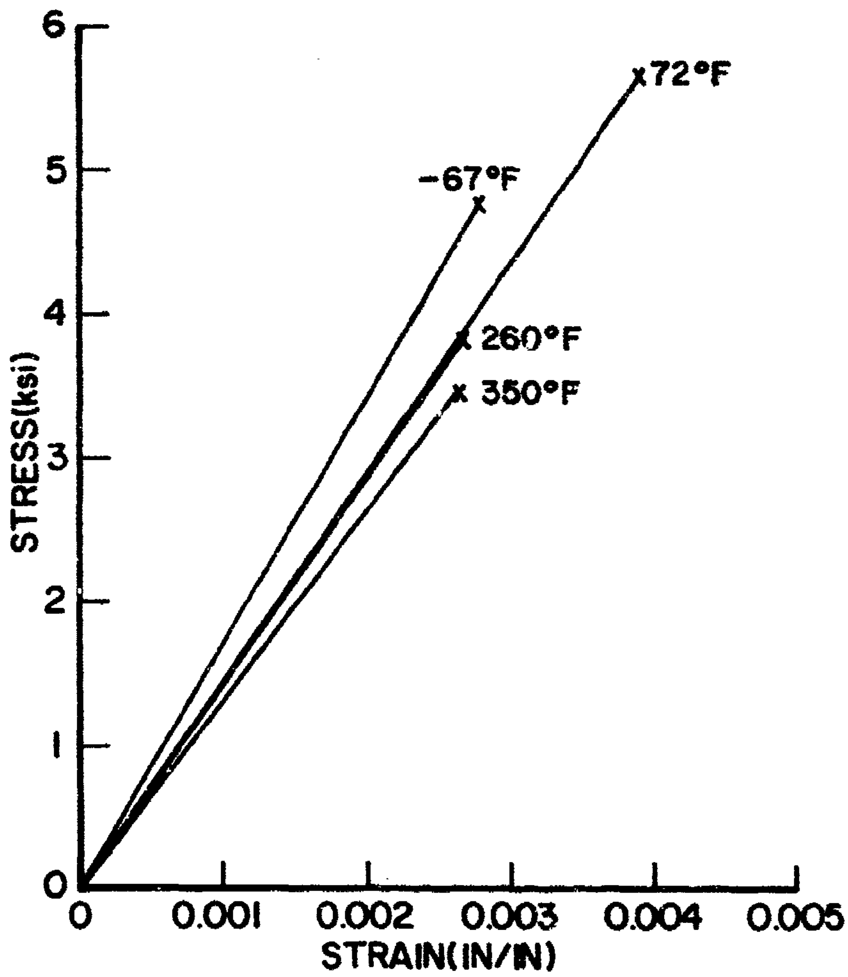


Figure 77. Tensile Stress-Strain Curves for Unidirectional HyE 1076J Composite Laminates: 90° Fiber Orientation.

TABLE 63

TENSILE PROPERTIES OF HyE 1076J
COMPOSITE LAMINATES

Composite Material Properties				
Material System - HyE 1076J Fiber - T300/15K Matrix - 976 Maximum Rated Temperature - 350°F(177°C) Resin Content - 25.3% by wt. Fiber Content - 67.9% by vol. Void Content - 0.2% by vol.	Prepreg by - Fiberite Laminate Sp. Gr. - 1.62 Nominal Ply Thickness - 0.0053 inch(0.13 mm) No. of panels from which specimens were tested in this table - 10 Thickness of specimen - 8 ply			Gr/Ep
TENSION: ±45°				
	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{tu} [ksi](MPa)	[27.49] (189)	[22.28] (154)	[16.49] (114)	[16.60] (114)
Stnd.Dev.[ksi](MPa)	[1.92] (13)	[0.28] (2)	[0.79] (5)	[1.29] (9)
Range [ksi](MPa)	[26.40 - 30.92] (182 - 213)	[22.0 - 22.73] (152 - 157)	[15.55 - 17.44] (107 - 120)	[15.33 - 18.71] (106 - 129)
No. of Specimens	5	5	5	5
F_x^{tpl} [ksi](MPa)	[13.61] (94)	[6.42] (44)	[4.36] (30)	[4.21] (29)
Stnd.Dev.[ksi](MPa)	[3.62] (25)	[1.85] (13)	[0.51] (4)	[0.57] (4)
No. of Specimens	5	5	5	5
E_x^t [Msi] (GPa)	[3.16] (22)	[3.08] (21)	[3.09] (21)	[2.68] (18)
Stnd.Dev.[Msi] (GPa)	[0.14] (1)	[0.10] (1)	[0.2] (1)	[0.17] (1)
No. of Specimens	5	5	5	5
ε_x^{tu} [μin/in](μcm/cm)	11,120	11,670	18,880	34,400
Stnd. Dev.	2,380	1,270	8,820	3,390
No. of Specimens	5	3[1]	5	2[2]
ν_{xy}^t	0.67	0.67	0.72	0.71
Stnd. Dev.	0.05	0.03	0.05	0.04
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3039			

[1]Strain gages failed on two specimens prior to fracture.
[2]Strain gages failed on three specimens prior to fracture.

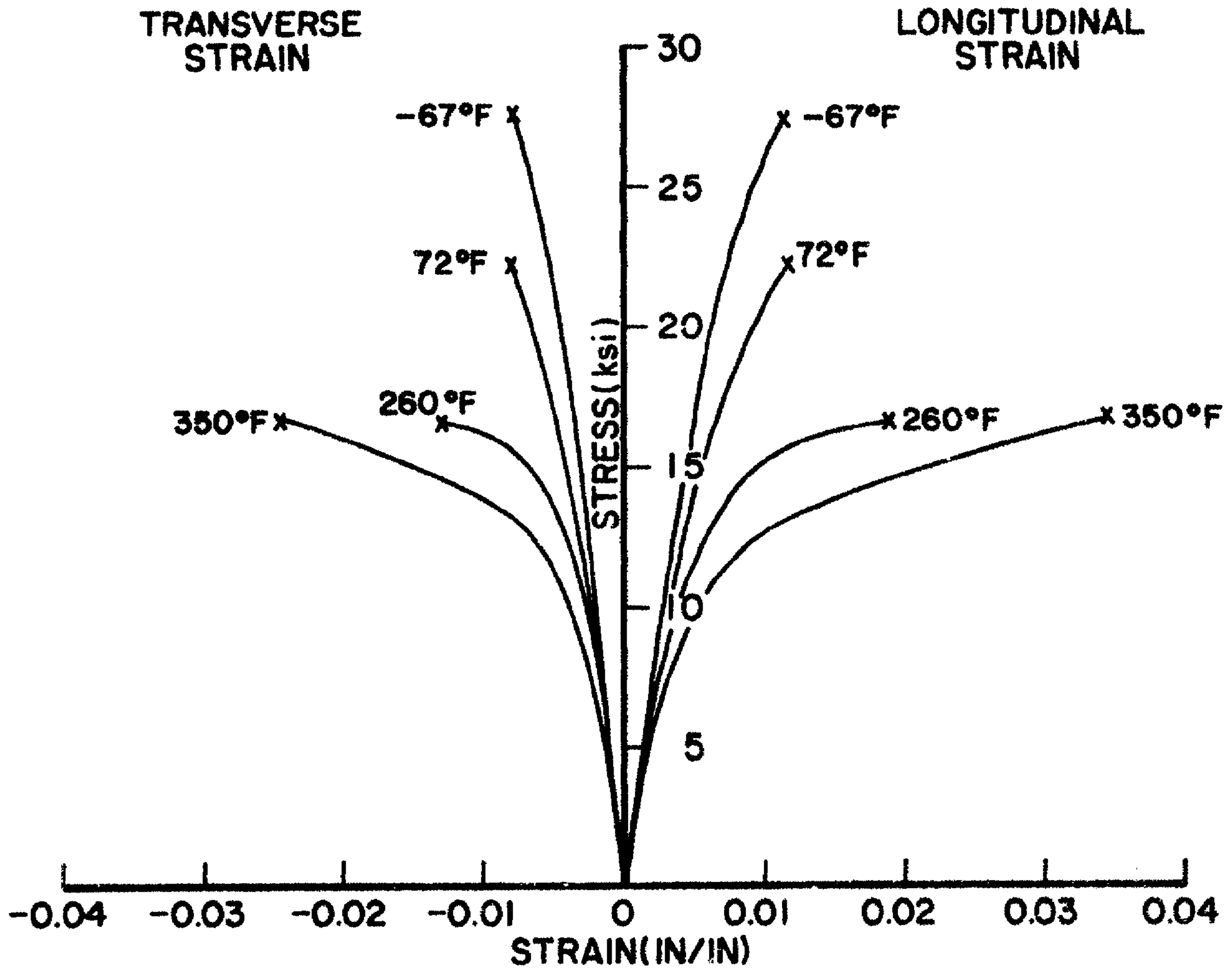


Figure 78. Tensile Stress-Strain Curves for Bidirectional HyE 1076J Composite Laminates: $\pm 45°$ Fiber Orientation.

TABLE 64

TENSILE PROPERTIES OF HyE 1076J COMPOSITE LAMINATES

Composite Material Properties

Material System - HyE 1076J Fiber - T300/15K Matrix - 976 Maximum Rated Temperature - 350°F(177°C) Resin Content - 25.4% by wt. Fiber Content - 68.4% by vol. Void Content - 0.3% by vol. Thickness of each type specimen: 20 ply	Prepreg by - Fiberite Laminate Sp. Gr. - 1.62 Nominal Ply Thickness - 0.0050 inch (0.13 mm) No. of panels from which specimens were tested in this table - 11	Gr/Ep

TENSION: (0, +45, -45, 0, 0, -45, +45, 0, 90, 0)$_s$

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{tu} [ksi](MPa)		[116.8] (805)	[120.1] (827)	[118.1] (814)
Stnd.Dev.[ksi](MPa)		[7.9] (54)	[5.9] (41)	[6.6] (45)
Range [ksi](MPa)		[108.9 - 128.1] (750 - 883)	[116.2 - 127.0] (801 - 875)	[109.3 - 126.3] (753 - 870)
No. of Specimens		5	5	5
F_x^{tpl} [ksi](MPa)		[116.8] (805)	[120.1] (827)	[118.1] (814)
Stnd.Dev.[ksi](MPa)		[7.9] (54)	[5.9] (41)	[6.6] (45)
No. of Specimens		5	5	5
E_x^t [Msi](GPa)		[11.2] (77)	[12.2] (84)	[11.9] (82)
Stnd.Dev.[Msi](GPa)		[0.5] (3)	[0.7] (5)	[0.8] (6)
No. of Specimens		5	5	5
ϵ_x^{tu} [μin/in](μcm/cm)		10,620	9,780	9,900
Stnd.Dev.		550	630	430
No. of Specimens		5	5	4[1]
ν_{xy}^t		0.37	0.40	0.36
Stnd. Dev.		0.01	0.03	0.04
No. of Specimens		5	5	5
Test Method Reference	ASTM D3039			

TENSION: (0, +45, -45, 0, 0, -45, +45, 0, 90, 0)$_s$ with 0.1935 inch (0.491 cm) hole

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_y^{tu} [ksi](MPa)		[88.5] (610)		
Stnd.Dev.[ksi](MPa)		[8.0] (55)		
Range		[78.6 - 99.1] (542 - 683)		
No. of Specimens		5		
F_y^{tpl} [ksi](MPa)				
Stnd.Dev.[ksi](MPa)				
No. of Specimens				
E_y^t [Msi] (GPa)				
Stnd.Dev.[Msi] (GPa)				
No. of Specimens				
ϵ_y^{tu} [μin/in](μcm/cm)				
Stnd. Dev.				
No. of Specimens				
ν_{yx}^t				
Stnd. Dev.				
No. of Specimens				
Test Method Reference	ASTM D3039			

[1] Gage failed on one specimen prior to end of test.

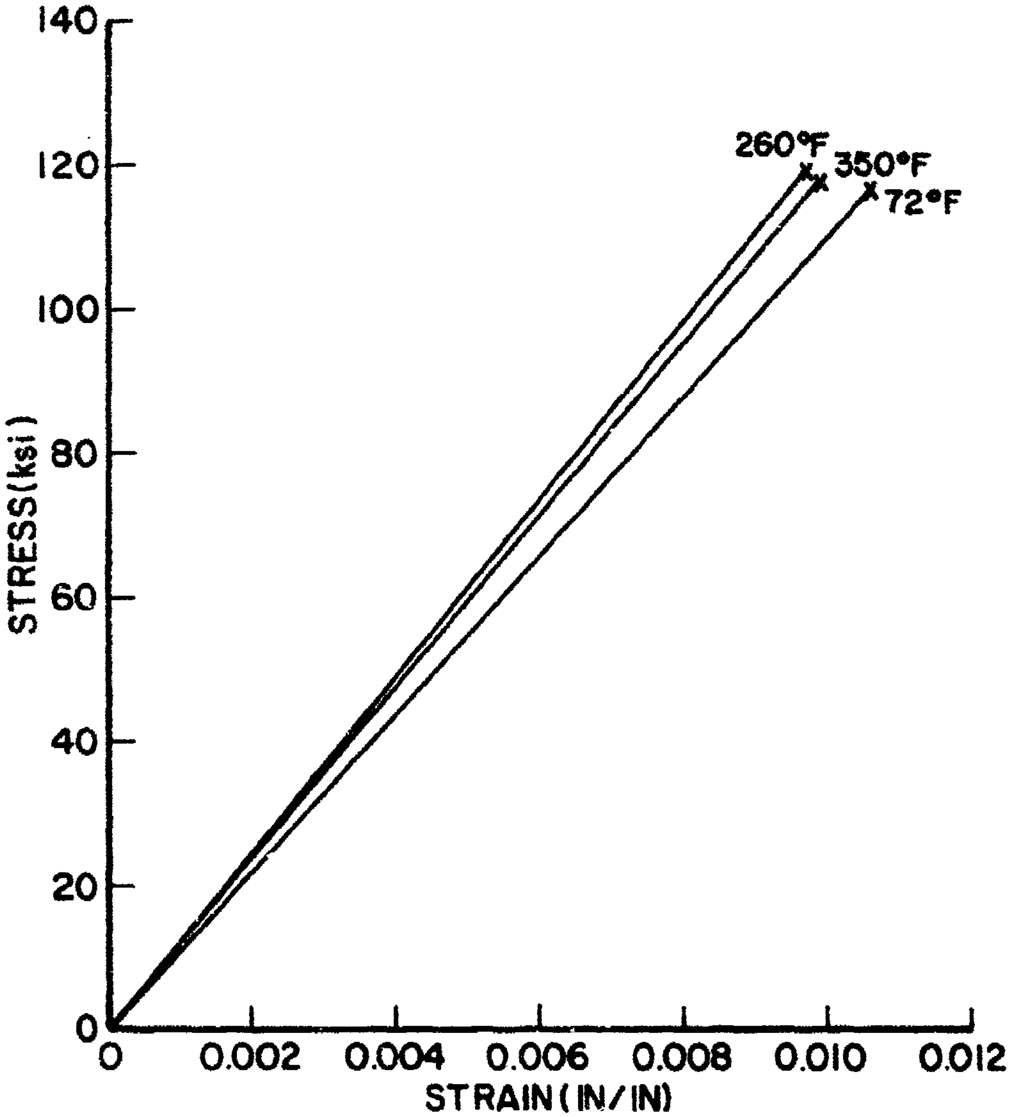


Figure 79. Tensile Stress-Strain Curves for Multidirectional HyE 1076J Composite Laminates: $(0,45-45,0,0,-45,45,0,90,0)_s$ Fiber Orientation.

TABLE 65

COMPRESSIVE PROPERTIES OF HyE 1076J COMPOSITE LAMINATES

Composite Material Properties

Material System - HyE 1076J	Prepreg by - Fiberite	Gr/Epoxy
Fiber -T300/15K Matrix - 976	Laminate Sp. Gr. - 1.63	
Maximum Rated Temperature - 350°F(177°C)	Nominal Ply Thickness - 0.0050 inch(0.13 mm)	
Resin Content - 24.3% by wt.	No. of panels from which specimens were tested in this table - 2	
Fiber Content - 69.5% by vol.		
Void Content - ≐ 0% by vol.		
Thickness of each type specimen: 0° - 20 ply ; 90° - 20 ply		

COMPRESSION: 0°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{cu} [ksi](MPa)	[223.4] (1539)	[218.2] (1503)	[170.9] (1178)	[158.5] (1092)
Stnd.Dev. [ksi](MPa)	[21.8] (150)	[34.7] (239)	[37.1] (256)	[29.3] (202)
Range [ksi](MPa)	[195.7 - 253.5] (1348 - 1747)	[161.9 - 248.1] (1115 - 1709)	[111.1 - 205.1] (765 - 1413)	[124.2 - 185.6] (856 - 1279)
No. of Specimens	5	5	5	5
F_x^{cpl} [ksi](MPa)	[63.8] (440)	[116.7] (804)	[62.9] (433)	[86.4] (595)
Stnd.Dev. [ksi](MPa)	[20.0] (138)	[88.9] (613)	[30.0] (207)	[34.6] (238)
No. of Specimens	5	5	5	5
E_x^c [Msi](GPa)	[21.9] (151)	[21.8] (150)	[21.4] (147)	[22.9] (158)
Stnd.Dev. [Msi](GPa)	[4.4] (30)	[2.9] (20)	[5.7] (39)	[3.0] (21)
No. of Specimens	5	5	5	5
ϵ_x^{cu} [μin/in](μcm/cm)	14,500+[1,2]	12,500+[1,3]	8,900+[1,3]	9,400
Stnd. Dev.	4,600	4,000	2,700	3,700
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3410			

COMPRESSION: 90°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_y^{cu} [ksi](MPa)	[35.1] (242)	[30.8] (212)	[22.6] (156)	[19.1] (132)
Stnd.Dev. [ksi](MPa)	[6.6] (45)	[1.3] (9)	[2.4] (17)	[2.2] (15)
Range	[26.7-44.9] (184 - 309)	[26.7-31.9] (184 - 220)	[19.4-25.7] (134 - 177)	[17.3-22.8] (119 - 157)
No. of Specimens	5	5	5	5
F_y^{cpl} [ksi](MPa)	[9.9] (68)	[11.0] (76)	[4.5] (31)	[7.1] (49)
Stnd.Dev. [ksi](MPa)	[3.9] (27)	[1.9] (13)	[1.0] (7)	[3.7] (25)
No. of Specimens	5	5	5	5
E_y^c [Msi](GPa)	[1.84] (13)	[1.46] (10)	[1.84] (13)	[1.64] (11)
Stnd.Dev. [Msi](GPa)	[0.31] (2)	[0.19] (1)	[0.68] (4)	[0.32] (2)
No. of Specimens	5	5	5	5
ϵ_y^{cu} [μin/in](μcm/cm)	22,100+[1,4]	32,300+[1,4]	17,600	14,200+[1,2]
Stnd. Dev.	6,400	14,400	---	6,700
No. of Specimens	5	5	2	5
Test Method Reference	ASTM D3410			

[1] Ultimate strain value represents maximum observed strain rather than ultimate values.
[2] Three of five specimens exhibited evidence of buckling.
[3] Two of five specimens exhibited evidence of buckling.
[4] One of five specimens exhibited evidence of buckling.

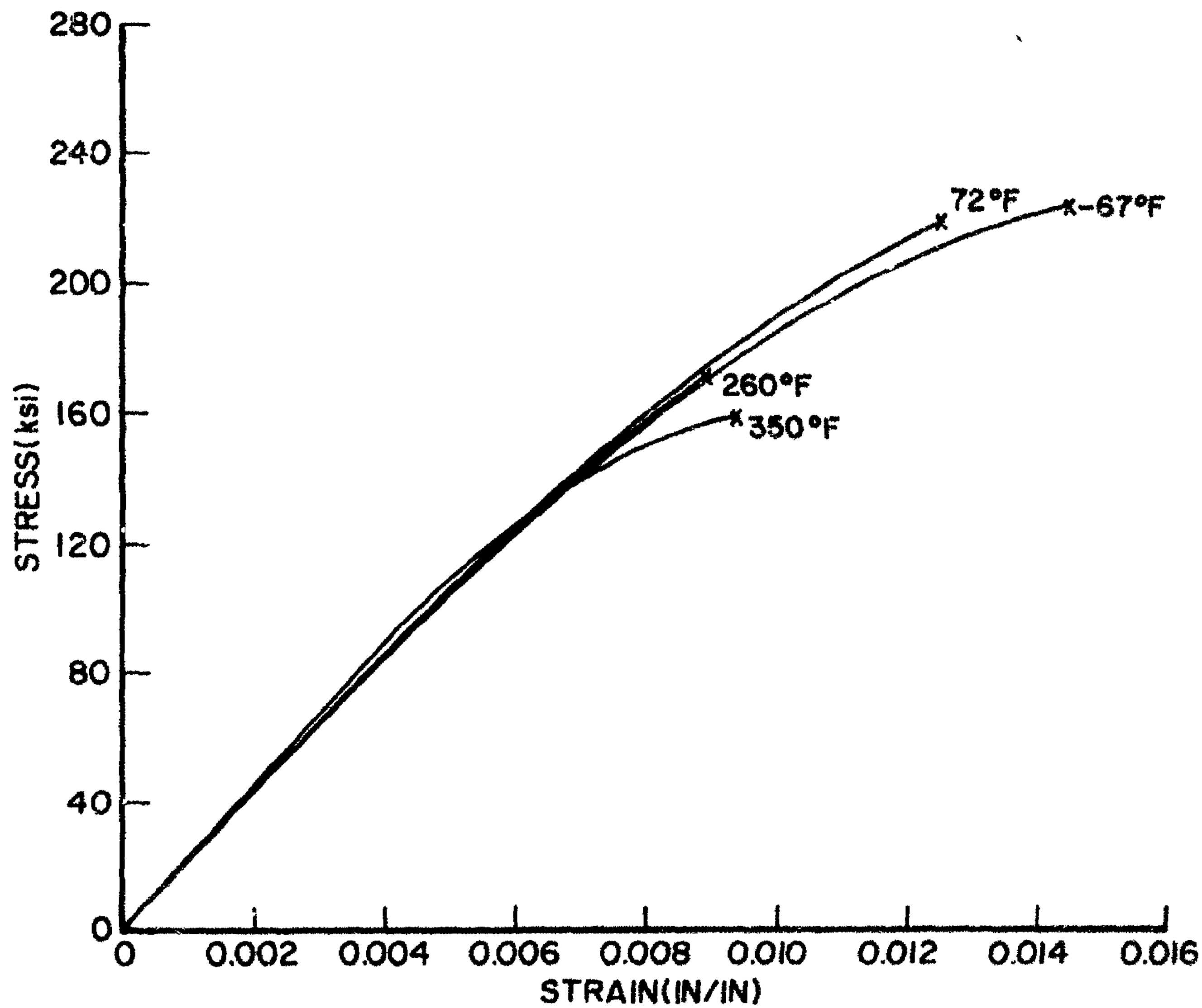


Figure 80. Compressive Stress-Strain Curves for Unidirectional HyE 1076J Composite Laminates: 0° Fiber Orientation.

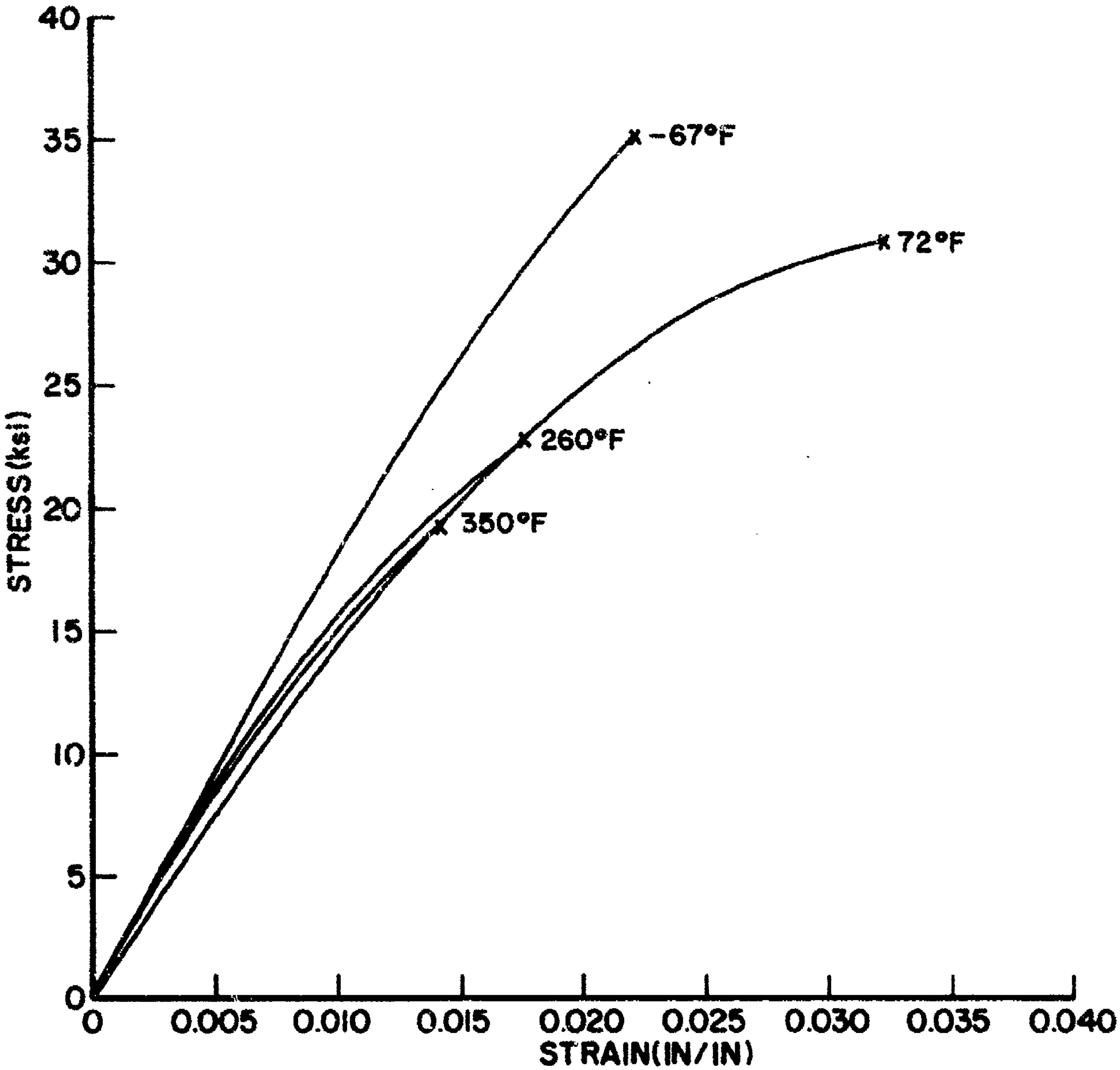


Figure 31. Compressive Stress-Strain Curves for Unidirectional HyE 1076J Composite Laminates: 90° Fiber Orientation.

TABLE 66

FLEXURAL PROPERTIES OF HyE 1076J
COMPOSITE LAMINATES

Composite Material Properties				
Material System - HyE 1076J Fiber - T300/15K Matrix - 976 Maximum Rated Temperature - 350°F(177°C) Resin Content - 25.1% by wt. Fiber Content - 68.0% by vol. Void Content - 0.6% by vol. Thickness of each type specimen: 0° - 14 ply ; 90° - 14 ply	Prepreg by - Fibarite Laminate Sp. Gr. - 1.62 Nominal Ply Thickness - 0.0050 inch (0.13 mm) No. of panels from which specimens were tested in this table - 2			Gr/Ep
FLEXURE: 0°				
	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{fu} [ksi] (MPa)	[261.9] (1804)	[190.1] (1310)[1]	[156.8] (1080)[2]	[185.9] (1281)[3]
Stnd.Dev. [ksi] (MPa)	[13.9] (96)	[3.6] (25)	[11.5] (79)	[8.2] (56)
Range [ksi] (MPa)	[239.3 - 276.3] (1649 - 1904)	[186.3 - 195.8] (1284 - 1349)	[148.1 - 176.2] (1020 - 1214)	[178.0 - 197.4] (1226 - 1360)
No. of Specimens	5	5	5	4
E_x^f [Msi] (GPa)	[18.6] (128)	[14.9] (103)	[13.1] (90)	[18.3] (126)
Stnd.Dev. [Msi] (GPa)	[0.7] (5)	[0.7] (5)	[0.8] (6)	[1.1] (8)
No. of Specimens	5	5	5	4
Test Method	3 pt. flex.	4 pt. flex.	4 pt. flex.	3 pt. flex.
Reference	Advanced Composite Design Guide; Jan. 1971[4]			
FLEXURE: 90°				
F_y^{fu} [ksi] (MPa)	[10.31] (71)	[8.79] (60)	[7.42] (51)	[7.03] (48)
Stnd.Dev. [ksi] (MPa)	[1.52] (10)	[1.19] (8)	[1.37] (9)	[1.16] (8)
Range [ksi] (MPa)	[8.34 - 11.78] (57 - 81)	[7.38 - 10.66] (51 - 73)	[5.85 - 9.06] (40 - 62)	[5.86 - 8.66] (40 - 60)
No. of Specimens	5	5	5	5
E_y^f [Msi] (GPa)	[1.84] (13)	[1.71] (81)	[1.62] (11)	[1.45] (10)
Stnd.Dev. [Msi] (GPa)	[0.21] (1)	[0.16] (1)	[0.10] (1)	[0.17] (1)
No. of Specimens	5	5	5	5
Test Method	4 pt. flexure			
Reference	Advanced Composite Design Guide; Jan. 1971[4]			

[1] All failures in tension on lower surface.
[2] All specimens exhibit compressive failure on upper surface.
[3] All specimens exhibit compressive failure on upper surface. One specimen tested in 4 pt. flexure failed in shear at a load corresponding to a flexural stress of 145.7 ksi (1004 MPa).
[4] This procedure corresponds to ASTM D790 except for loading speed and, in the case of the 4 pt. test, the position of the upper loading points.

TABLE 67

SHEAR PROPERTIES OF HyE 1076J
COMPOSITE LAMINATES

Composite Material Properties				
Material System - HyE 1076J Prepreg by - Fiberite Fiber - T300/15K Matrix - 976 Maximum Rated Temperature - 350°F(177°C) Resin Content - 24.7% by wt. Fiber Content - 68.8% by vol. Void Content - ≤0.1% by vol. Thickness of each type specimen - Inplane - 8 ply ; Interlaminar - 15 ply			Laminate Sp. Gr. - 1.63 Nominal Ply Thickness - 0.0052 inch (0.13 mm) No. of panels from which specimens were tested in this table - 11	Gr/Ep
INPLANE SHEAR				
	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F^{su}_{xy} [ksi] (MPa)	[13.75] (95)	[11.14] (77)	[8.25] (57)	[8.30] (57)
Stnd.Dev. [ksi] (MPa)	[0.96] (7)	[0.14] (1)	[0.39] (3)	[0.65] (4)
Range [ksi] (MPa)	[13.20 - 15.46] (91 - 107)	[11.08-11.36] (76-78)	[7.78 - 8.72] (54 - 60)	[7.67 - 9.36] (53-64)
No. of Specimens	5	5	5	5
G^{s}_{xy} [Msi] (GPa)	[1.00] (7)	[0.92] (6)	[0.89] (6)	[0.77] (5)
Stnd.Dev. [Msi] (GPa)	[0.07] (1)	[0.05] (1)	[0.05] (1)	[0.06] (1)
No. of Specimens	5	5	5	5
Test Method Reference	±45° straight-sided tension J. Comp. Mtls. (Vol. 6, p. 252 & Vol. 7, p. 124)			
INTERLAMINAR SHEAR				
F^{isu} [ksi] (MPa)	[16.62] (115)	[12.87] (89)	[9.36] (64)	[8.60] (59)
Stnd.Dev. [ksi] (MPa)	[2.12] (15)	[2.36] (16)	[0.95] (6)	[0.69] (5)
Range	[14.24 - 19.64] (98 - 135)	[9.42 - 17.11] (65 - 118)	[8.59 - 10.79] (59 - 74)	[7.72 - 9.56] (53 - 66)
No. of Specimens	5	10	5	5
Test Method Reference	ASTM D2344			

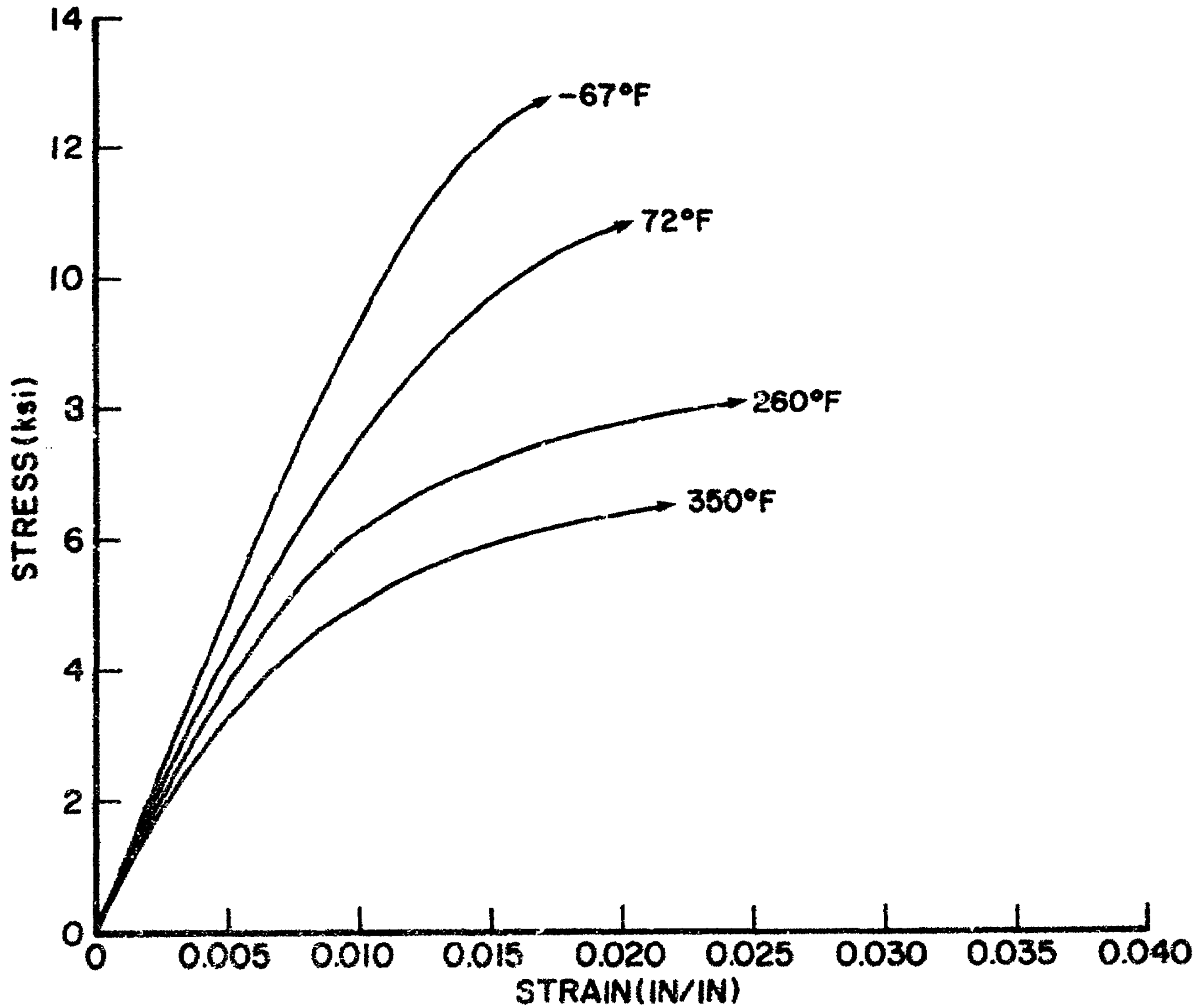


Figure 82. Inplane Shear Stress-Strain Curves for HyE 1076 Composite Laminates.

TABLE 68

TENSILE, COMPRESSIVE, AND SHEAR PROPERTIES OF HyE 1076J COMPOSITE LAMINATES AFTER HUMIDITY AGING

Composite Material Properties — Gr/Ep

Material System - HyE 1076J
Fiber - T300/15K Matrix - 976
Maximum Rated Temperature - 350°F
Resin Content - 24.4% by wt.(177°C)
Fiber Content - 69.5% by wt.
Void Content - ± 0% by vol.
Thickness of each type specimen: Tension - 15 ply; Compr. - 20 ply; Shear - 15 ply

Prepreg by - Fiberite
Laminate Sp. Gr. - 1.63
Nominal Ply Thickness - 0.0050 in.(0.13mm)
No. of panels from which specimens were tested in this table - 6
Aging Conditions - 160°F(71°C)&100% R.H.

TENSION: 90°

	72°F(22°C)	260°F(127°C)	72°F(22°C)	260°F(127°C)
Exposure Time (hrs)	162	162	1774	1774
Wt. Gain(% of orig. dry wt.)	0.77	0.76	1.17[1]	1.17[1]
Stnd. Dev.(%)	0.04	0.03	0.02	0.01
No. of Specimens	5	5	5	5
F_y^{tu} [ksi](MPa)	[4.80](33)	[2.90](20)	[4.03](28)	[1.49](10)
Stnd. Dev. [ksi](MPa)	[0.73](5)	[0.47](3)	[0.18](1)	[0.42](3)
Range [ksi](MPa)	[4.14-5.98] (29 - 41)	[2.47-3.63] (17 - 25)	[3.80-4.26] (26 - 29)	[1.09-1.99] (8 - 18)
No. of Specimens	5	5	5	5
F_y^{tpl} [ksi](MPa)	[3.49](24)	[1.31](9)	[3.83](26)	[1.05](7)
Stnd. Dev. [ksi](MPa)	[1.63](11)	[0.64](4)	[0.59](4)	[0.24](2)
No. of Specimens	5	5	5	5
E_y^t [Msi](GPa)	[1.41](10)	[1.20](8)	[1.41](10)	[1.03](7)
Stnd. Dev. [Msi](GPa)	[0.09](1)	[0.09](1)	[0.10](1)	[0.16](1)
No. of Specimens	5	5	5	5
ϵ_y^{tu} [μin/in](μcm/cm)	3,500	2,700	2,800	1,480
Stnd. Dev.	540	370	100	300
No. of Specimens	5	5	5	5
Test Method Reference	Straight-sided tension ASTM D3039			

COMPRESSION: 90°

	72°F(22°C)	260°F(127°C)	72°F(22°C)	260°F(127°C)
Exposure Time(hrs)	161	161	1242	1242
Wt. Gain(% of orig. dry wt.)	0.73	0.74	1.09[1]	1.05[1]
Stnd. Dev. (%)	0.05	0.05	0.02	0.05
No. of Specimens	5	5	5	5
F_y^{cu} [ksi](MPa)	[22.7](156)	[20.8](143)	[25.5](176)	[19.5](134)
Stnd. Dev. [ksi](MPa)	[6.6](45)	[2.1](14)	[2.8](19)	[2.6](18)
Range	[11.3-28.3] (78 - 195)	[19.2-24.3] (132 - 167)	[21.8-29.3] (150 - 202)	[17.9-23.4] (123 - 161)
No. of Specimens	4	5	5	5
F_y^{cpl} [ksi](MPa)	[3.8] (26)	[4.0] (38)	[10.4](72)	[6.7](46)
Stnd. Dev. [ksi](MPa)	[1.6] (11)	[1.4] (10)	[2.7](19)	[2.1](14)
No. of Specimens	4	5	5	5
E_y^c [Msi](GPa)	[2.22](15)	[1.91](13)	[1.63](11)	[1.64] (11)
Stnd. Dev. [Msi](GPa)	[0.16] (1)	[0.39](3)	[0.21] (1)	[0.50] (3)
No. of Specimens	4	5	5	5
ϵ_y^{cu} [μin/in](μcm/cm)	21,450	18,860[2]	31,700[3]	22,220
Stnd. Dev.	7,090	10,850	9,890	8,250
No. of Specimens	4	4	3	5
Test Method Reference	ASTM D3410			

INTERLAMINAR SHEAR

	72°F(22°C)	260°F(127°C)	72°F(22°C)	260°F(127°C)
Exposure Time(hrs)	188	188	1675	1675
Wt. Gain(% of orig. dry wt.)	0.53	0.64	1.11[1]	1.21[1]
Stnd. Dev. (%)	0.17	0.28	0.16	0.05
No. of Specimens	10	5	10	5
F^{isu} [ksi](MPa)	[11.88](81.9)	[8.44](58.2)	[11.98](82.5)	[6.84](47.1)
Stnd. Dev. [ksi](MPa)	[1.68](11.6)	[1.57](10.8)	[1.55](10.7)	[0.54](3.72)
Range [ksi](MPa)	[9.62-15.17] (66.3-104.5)	[6.45-9.92] (44.4-68.3)	[9.42-14.10] (64.9-97.1)	[6.44-7.78] (44.4-53.6)
No. of Specimens	10	5	10	5
Test Method Reference	ASTM D2344			

[1] Represents 100% saturation at aging conditions.
[2] One of five specimens exhibited evidence of buckling.
[3] Two of five specimens exhibited evidence of buckling.

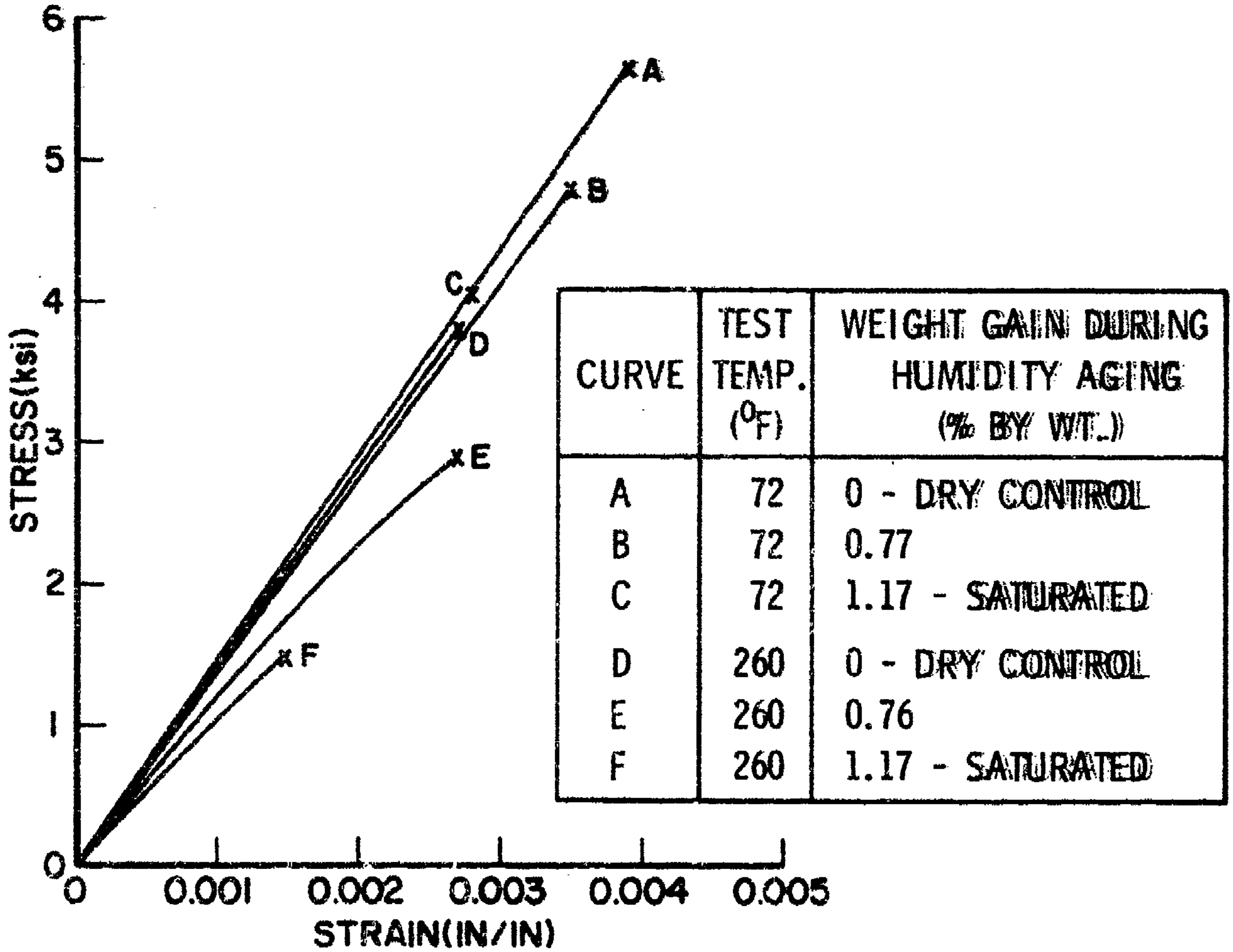
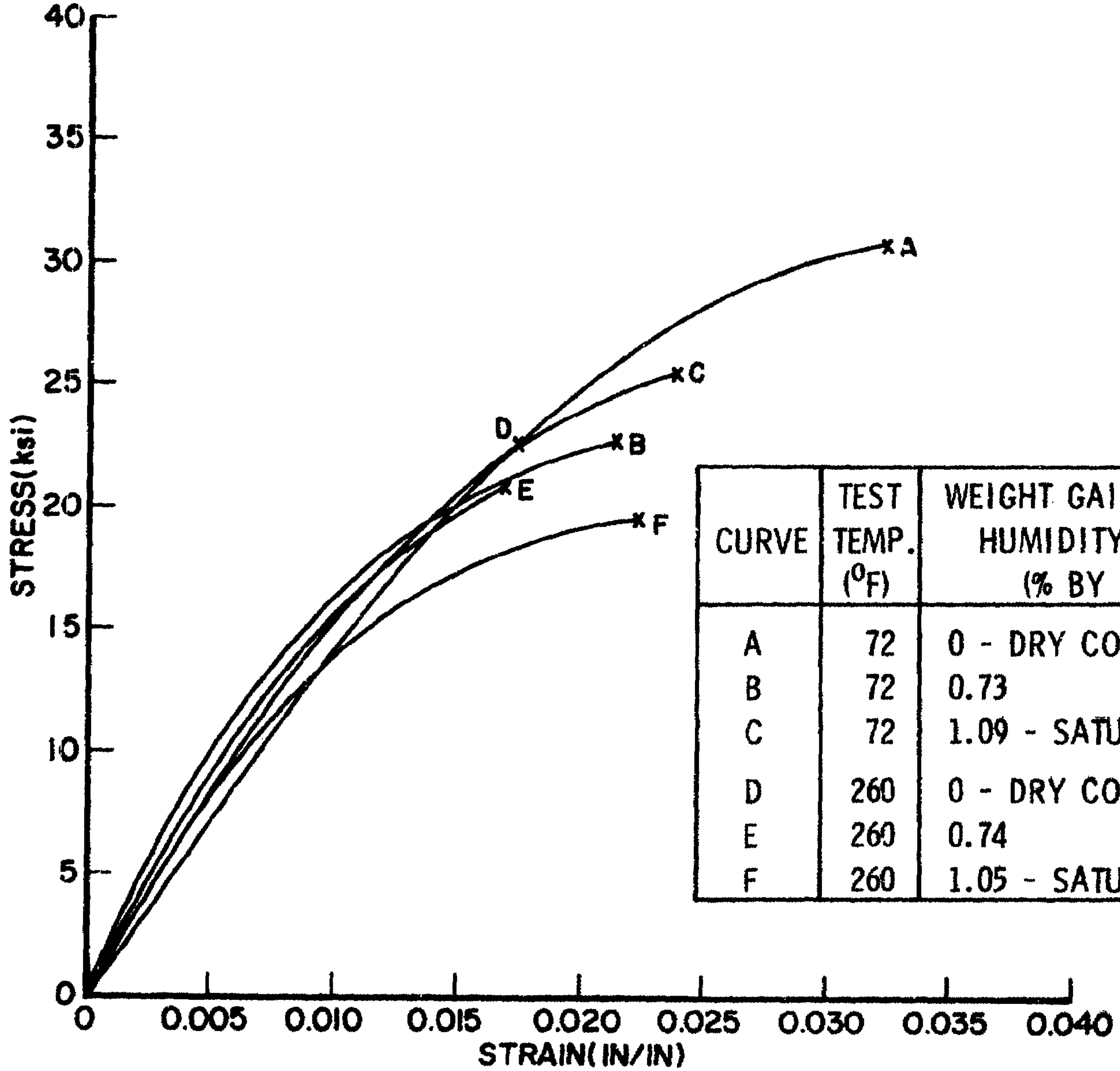


Figure 83. Tensile Stress-Strain Curves for Unidirectional HyE 1076J Composite Laminates After Humidity Aging at 160°F (71°C) and 100% R.H.: 90° Fiber Orientation.



CURVE	TEST TEMP. (°F)	WEIGHT GAIN DURING HUMIDITY AGING (% BY WT.)
A	72	0 - DRY CONTROL
B	72	0.73
C	72	1.09 - SATURATED
D	260	0 - DRY CONTROL
E	260	0.74
F	260	1.05 - SATURATED

Figure 84. Compressive Stress-Strain Curves for Unidirectional HyE 1076J Composite Laminates After Humidity Aging at 160°F (71°C) and 100% R.H.: 90° Fiber Orientation.

TABLE 69

CREEP PROPERTIES OF HyE 1076J COMPOSITE LAMINATES

Composite Material Properties

Material System - HyE 1076J	Prepreg by - Fiberite — Gr/Ep
Fiber - T300/15K Matrix - 976	Laminate Sp. Gr. - 1.62
Maximum Temperature Rating - 350°F(177°C)	Nominal Ply Thickness - 0.0053 inch(0.13 mm)
Resin Content - 25.2% by wt.	No. of panels from which specimens were tested in this table - 16
Fiber Content - 68.0% by vol.	Thickness of each type specimen:
Void Content - ± 0.3% by vol.	0/45/90 - 20 ply
Test Method - Straight-sided tension	±45 - 8 ply
Reference - ASTM D2290 and D3039	

CREEP

Temperature	Fiber Orientation	$(0,+45,-45,0,0,-45,+45,0,90,0)_s$	±45°
72°F(22°C)	Stress Level [ksi](MPa)	[93.5] (644)	[20.05] (138)
	Creep Strain, 500 hr(%)	0.0239	—[1]
	No. of Specimens	1[3]	3
	Residual Strength(ksi)(MPa)	[130.9] (902)	—
	No. of Specimens	1	0
	Stress Level [ksi](MPa)	[81.8] (564)	[17.83] (123)
	Creep Strain, 500 hr(%)	0.0121	0.3005
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[115.6] (796)	[24.40] (168)
	No. of Specimens	3	3
	Stress Level [ksi](MPa)	[70.1] (483)	[15.60] (107)
	Creep Strain, 500 hr(%)	0.0254	0.2074
	No. of Specimens	1	3
	Residual Strength(ksi)(MPa)	[104.3] (719)	[23.35] (161)
	No. of Specimens	1	3
260°F(127°C)	Stress Level [ksi](MPa)	[96.1] (662)	[13.19] (91)
	Creep Strain, 500 hr(%)	0.0003[5]	—[2]
	No. of Specimens	1	3
	Residual Strength(ksi)(MPa)	[134.3] (925)	[22.45] (155)
	No. of Specimens	1	3
	Stress Level [ksi](MPa)	[84.1] (579)	[11.55] (80)
	Creep Strain, 500 hr(%)	0.0002	0.3870[4]
	No. of Specimens	3	2
	Residual Strength(ksi)(MPa)	[111.4] (768)	[22.72] (157)
	No. of Specimens	3	2
	Stress Level [ksi](MPa)	[72.0] (496)	[9.90] (68)
	Creep Strain, 500 hr(%)	0.0109	0.4191
	No. of Specimens	3	3
	Residual Strength(ksi)(MPa)	[111.6] (769)	[20.88](144)
	No. of Specimens	3	3
350°F(177°C)	Stress Level [ksi](MPa)	[94.5] (651)	[13.28] (91)
	Creep Strain, 500 hr(%)	0.0183[7]	—[2]
	No. of Specimens	2	3
	Residual Strength(ksi)(MPa)	[119.2] (821)	[21.64] (149)
	No. of Specimens	-2-	3
	Stress Level [ksi](MPa)	[82.7] (570)	[11.62] (80)
	Creep Strain, 500 hr(%)	0.0607	0.8734[6]
	No. of Specimens	3	1
	Residual Strength(ksi)(MPa)	[112.0] (772)	[20.93] (144)
	No. of Specimens	3	3
	Stress Level [ksi](MPa)	[70.9] (489)	[9.96] (69)
	Creep Strain, 500 hr(%)	0.0754	—[2]
	No. of Specimens	3	3
	Residual Strength(ksi)(MPa)	[115.8] (798)	[19.52] (134)
	No. of Specimens	3	3

[1] Three specimens failed on loading or during test.
[2] Strain exceeded limits of gage capabilities prior to end of test.
[3] Two specimens broke on loading.
[4] One specimen failed during test.
[5] Strain gages failed on two specimens during test.
[6] Two specimens failed during test.
[7] One specimen failed on loading.

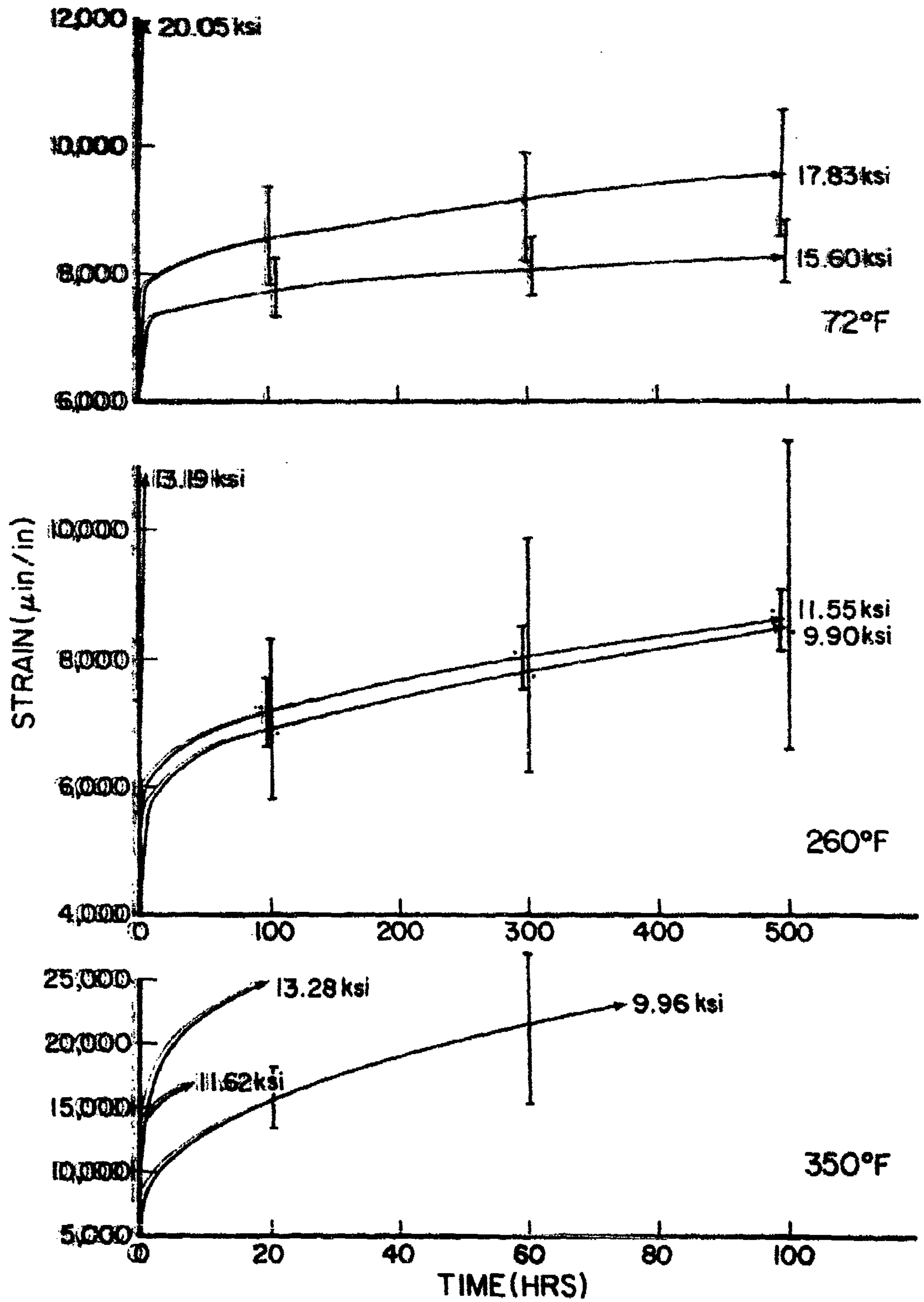


Figure 85. Tensile Creep Behavior of Bidirectional HyE 1076J Composite Laminates: ±45° Fiber Orientation.

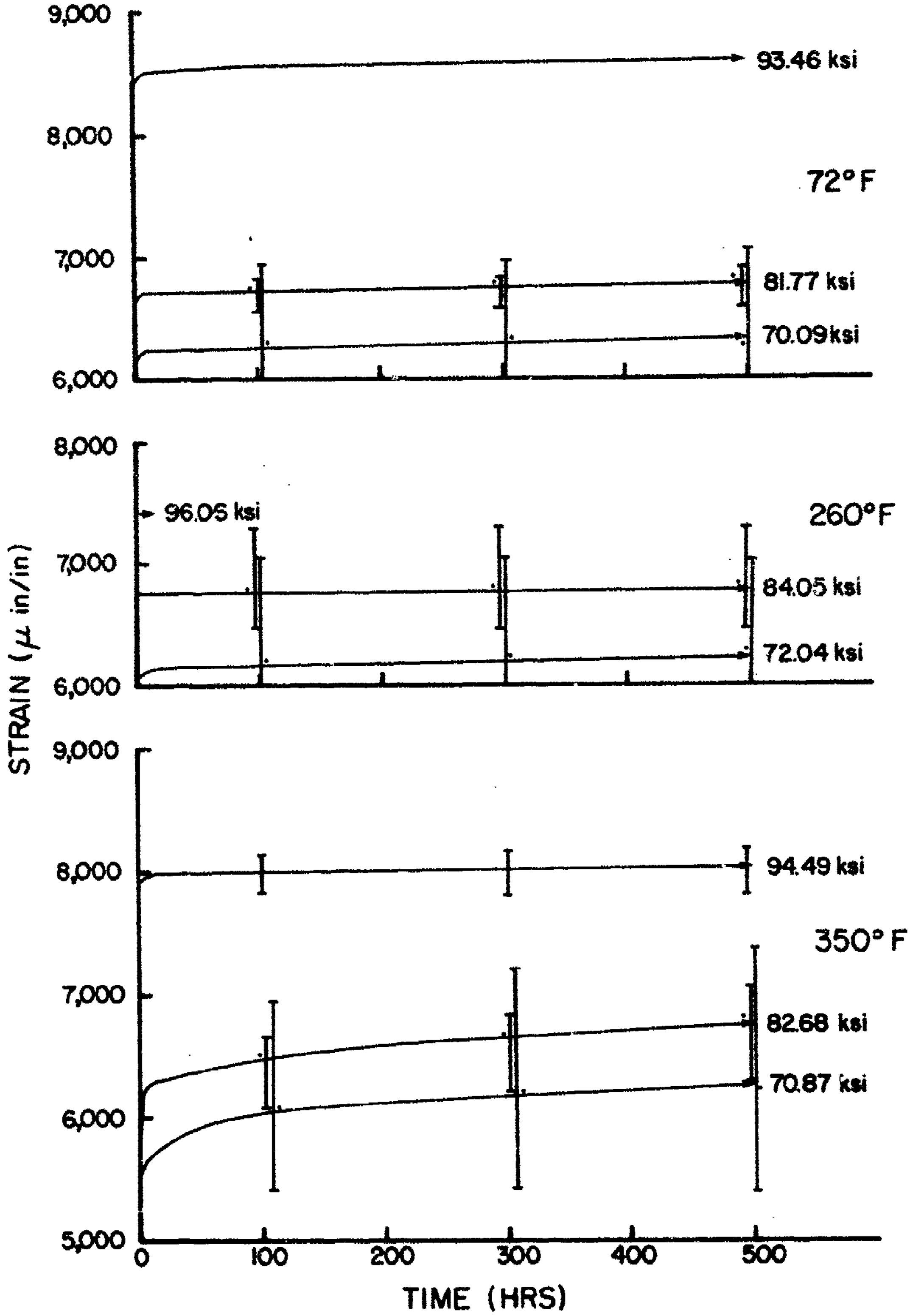


Figure 86. Tensile Creep Behavior of HyE 1076J Composite Laminates: $(0,+45,-45,0,0,-45,+45,0,90,0)_s$ Fiber Orientation.

TABLE 70

STRESS-RUPTURE BEHAVIOR OF HyE 1076J COMPOSITE LAMINATES

Composite Material Properties			
Material System - HyE 1076J Fiber - T300/15K Matrix - 976 Maximum Temperature Rating - 350°F(177°C) Resin Content - 25.2% by wt. Fiber Content - 68.0% by vol. Void Content - ≈0.3% by vol. Test Method - Straight-sided tension Reference - ASTM D2290 and D3039		Prepreg by - Fiberite Laminate Sp. Gr. - 1.62 Nominal Ply Thickness - 0.0053 inch (0.13 mm) No. of panels from which specimens were tested in this table - 16 Thickness of each type specimen: (0/±45/90) - 20 ply ±45 - 8 ply	Gr/Epoxy

STRESS RUPTURE

Temperature	Fiber Orientation	$(0,+45,-45,0,0,-45,+45,0,90,0)_s$	±45°
72°F (22°C)	Stress Level[ksi](MPa)	[93.5] (644)	[17.83] (123)
	Time to Failure(hrs)	167+[1]	500+
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[130.9] (902)	[24.40] (168)
	No. of Specimens	1	3
	Stress Level[ksi](MPa)	[81.8] (564)	[15.60] (107)
	Time to Failure(hrs)	500+	500+
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[115.6] (796)	[23.35] (161)
	No. of Specimens	3	3
260°F(127°C)	Stress Level[ksi](MPa)	[96.1] (662)	[13.19] (91)
	Time to Failure(hrs)	256+[2]	500+
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[134.3] (925)	[22.45] (155)
	No. of Specimens	1	3
	Stress Level[ksi](MPa)	[84.1] (579)	[9.90] (68)
	Time to Failure(hrs)	500+	500+
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[111.4] (768)	[20.88] (144)
	No. of Specimens	3	3
350°F(177°C)	Stress Level[ksi](MPa)	[94.5] (651)	[13.28] (91)
	Time to Failure(hrs)	334+[3]	500+
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[119.2] (821)	[21.64] (149)
	No. of Specimens	2	3
	Stress Level[ksi](MPa)	[82.7] (570)	[11.62] (80)
	Time to Failure(hrs)	500+	500+
	No. of Specimens	3	3
	Residual Strength[ksi](MPa)	[112.0] (772)	[20.93] (144)
	No. of Specimens	3	3

[1]Two specimens broke on loading.
[2]Two specimens broke during test.
[3]One specimen broke on loading.

TABLE 71

TENSILE-TENSILE FATIGUE PROPERTIES OF HyE 1076J COMPOSITE LAMINATES

Composite Material Properties

Material System - HyE 1076J	Prepreg by - Fiberite
Fiber - T300/15K Matrix - 976	Gr/Ep
Maximum Temperature Rating - 350°F(177°C)	Laminate Sp. Gr. - 1.62
Resin Content - 25.2% by wt.	Nominal Ply Thickness - 0.0052 inch (0.13 mm)
Fiber Content - 68.1% by vol.	No. of panels from which specimens were tested in this table - 20
Void Content - 0.2% by vol.	Thickness of each type specimen:
Test Method - Straight-sided tension	±45 - 8 ply
Reference - ASTM D3039	0/±45/90 - 20 ply

TENSILE FATIGUE[3], R=0.1

Temperature	Fiber Orientation	±45°	0/±45/90[1]	0/±45/90[1,2]
72°F(22°C)	Max. Stress [ksi] (MPa)	[17.82] (123)	[105.1] (724)	[97.4] (671)
	Lifetime (cycles)	5,701	19,153	735
	No. of Specimens	5	5	2
	Residual Strength [ksi] (MPa)	—	—	—
	No. of Specimens	0	0	0
	Max. Stress [ksi] (MPa)	[15.60] (107)	[102.2] (704)	[92.9] (640)
	Lifetime (cycles)	136,004	182,507	6421
	No. of Specimens	5	3	4
	Residual Strength [ksi] (MPa)	—	—	—
	No. of Specimens	0	0	0
	Max. Stress [ksi] (MPa)	[14.48] (100)	[99.3] (684)	[88.5] (610)
	Lifetime (cycles)	1,120,500	598,592	94,313
	No. of Specimens	4	5	5
	Residual Strength [ksi] (MPa)	—	—	[118.3] (815)
	No. of Specimens	0	0	1
260°F(127°C)	Max. Stress [ksi] (MPa)	[14.02] (97)	[108.1] (745)	
	Lifetime (cycles)	23,206	4,850	
	No. of Specimens	5	4	
	Residual Strength [ksi] (MPa)	—	—	
	No. of Specimens	0	0	
	Max. Stress [ksi] (MPa)	[13.19] (91)	[96.1] (662)	
	Lifetime (cycles)	71,048	84,188	
	No. of Specimens	5	5	
	Residual Strength [ksi] (MPa)	—	—	
	No. of Specimens	0	0	
	Max. Stress [ksi] (MPa)	[12.37] (85)	[90.1] (621)	
	Lifetime (cycles)	488,973	1,438,881	
	No. of Specimens	5	5	
	Residual Strength [ksi] (MPa)	—	—	
	No. of Specimens	0	0	

[1] Stacking sequence $(0,+45,-45,0,0,-45,+45,0,90,0)_s$.

[2] These specimens had a 0.1935 inch (0.491 cm) hole in the center of the test section. Stresses calculated using net cross-sectional area.

[3] Fatigue lifetimes are log-mean values.

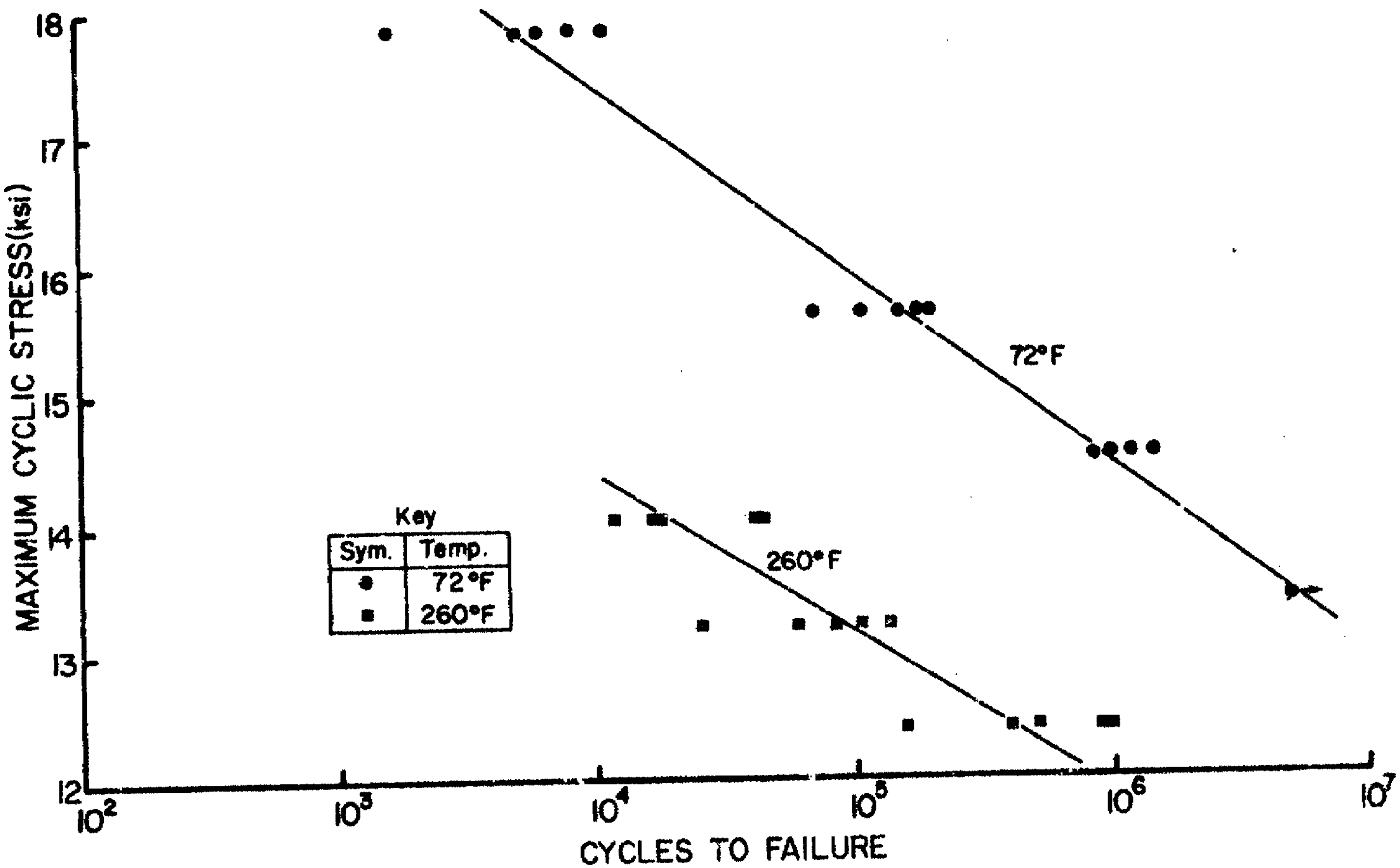


Figure 87. Tensile-Tensile Fatigue Behavior of Bidirectional HyE 1076J Composite Laminates: ±45° Fiber Orientation, R = 0.10, 10 Hz.

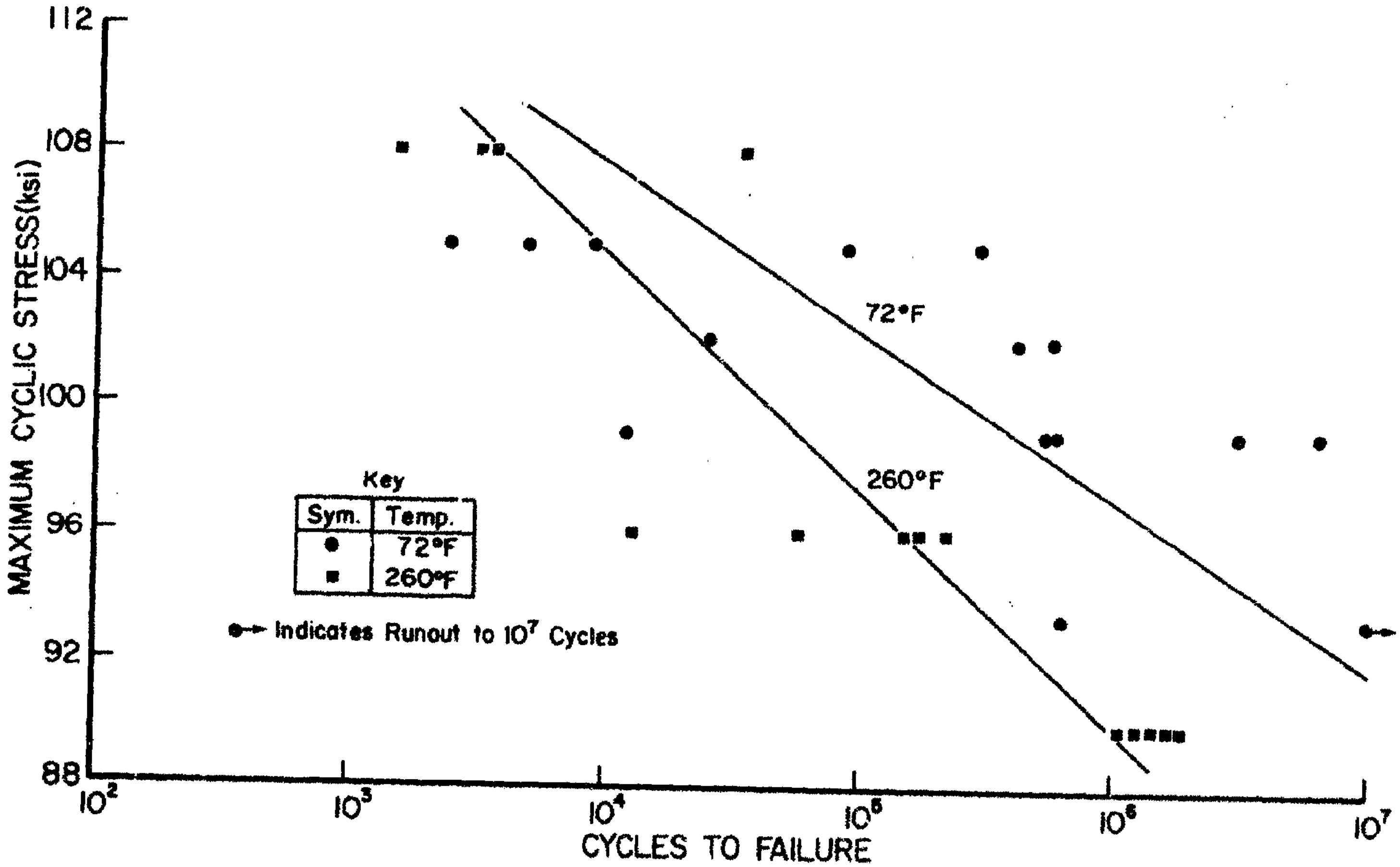


Figure 88. Tensile-Tensile Fatigue Behavior of Multidirectional HyE 1076J Composite Laminates: $(0,45,-45,0,0,-45,45,0,90,0)_s$ Fiber Orientation, R = 0.10, 10 Hz.

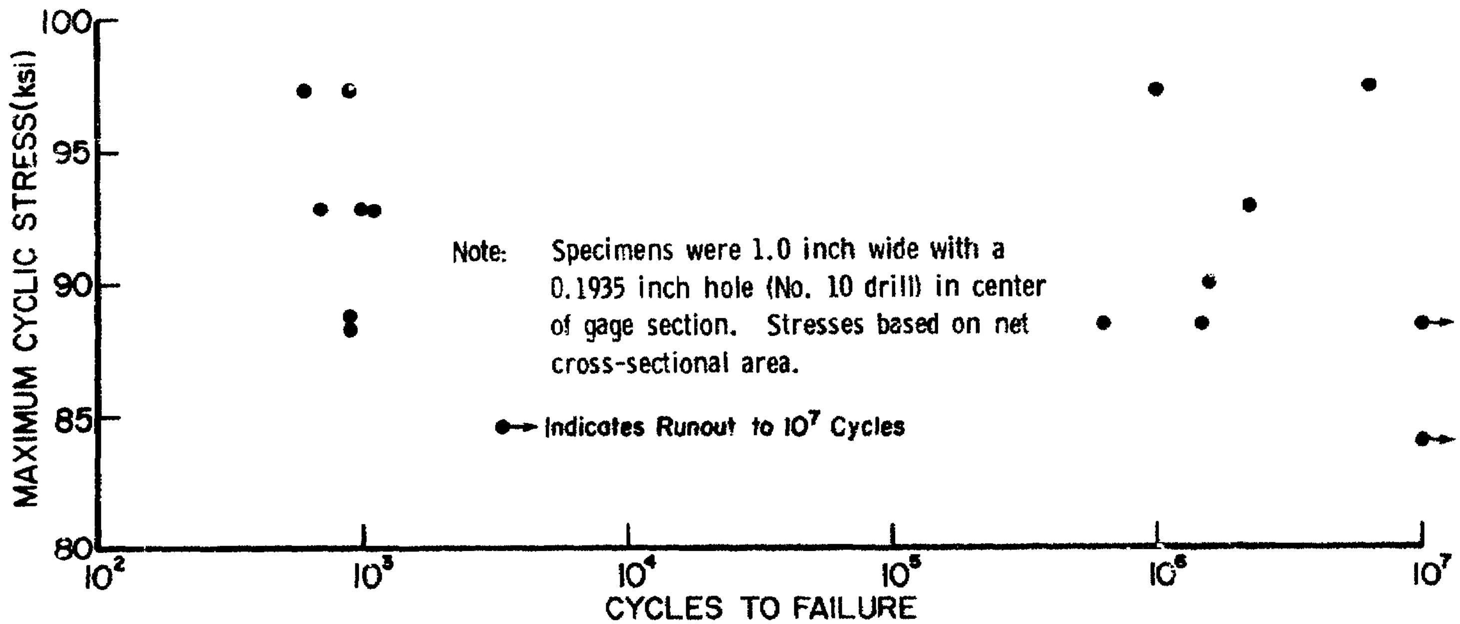


Figure 89. Tensile-Tensile Fatigue Behavior of Multidirectional HyE 1076J Composite Laminates: $(0,45,-45,0,0,-45,45,0,90,0)_s$ Fiber Orientation, R = 0.10, 10 Hz.

TABLE 72

THERMOPHYSICAL PROPERTIES OF HyE 1076J COMPOSITE LAMINATES

Composite Material Properties

Material System - HyE 1076J	Prepreg by - Fiberite	Gr/Epoxy
Fiber - T300/15K Matrix - 976	Laminate Sp. Gr. - 1.62	
Maximum Temperature Rating - 350°F(177°C)	Average Ply Thickness - 0.00050 inch(0.13 mm)	
Resin Content - 25.6% by wt.	No. of panels from which specimens were tested in this table - 2	
Fiber Content - 67.7% by vol.		
Void Content - ≐ 0% by vol.		
Thickness of each type specimen: Therm. Exp. - 40 ply; Therm. Cond. - 40 ply	Spec. Ht. - 1 ply; Glass Trans. - 8 ply	

THERMOPHYSICAL PROPERTIES: 0°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)	Test Method
Thermal Expansion[1]					
α_x [μin/in-°F] (μcm/cm-°C)	[0.08] (0.15)	[-0.30] (-0.54	[-0.24] (-0.44	[-0.18] (-0.32)	TMA[2]
α_y [μin/in-°F] (μcm/cm-°C)	[12.5] (22.5)	[13.6] (24.4)	[17.4] (31.4)	[19.2] (34.6)	
No. of Specimens per direction	3	3	3	3	
Specific Heat					
C_p [btu/lb.-°F] (J/kg-°C)	[0.153] (640)	[0.205] (860)	[0.274] (1150)	[0.330] (1380)	DSC[3]
No. of Specimens	3	3	3	3	
Thermal Conductivity[1]					
k_z [btu-ft/ft^2-hr-°F] (W/m-°C)	[0.37] (0.64)	[0.42] (0.72)	[0.48] (0.84)	[0.51] (0.89)	Comparative
No. of Specimens	3	3	3	3	
Glass Transition Temp.					DMA[4]
Dry [°F] (°C)	[518] (270)				
Wet [°F] (°C)	[493] (256)				

THERMOPHYSICAL PROPERTIES: ±45°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)	Test Method
Thermal Expansion[1]					
α_x [μin/in-°F] (μcm/cm-°C)	[1.7] (3.1)	[1.4] ([illegible].6)	[1.4] (2.5)	[1.5] (2.7)	TMA[2]
No. of Specimens per direction	3	3	3	3	
Thermal Conductivity[1]					Comparative
k_z [btu-ft/ft^2-hr-°F] (W/m-°C)	[0.28] (0.48)	[0.39] (0.67)	[0.53] (0.92)	[0.61] (1.05)	
No. of Specimens	3	3	3	3	

NOTES: 1. On the unidirectionally reinforced specimens, the x-direction is along the fiber axis, the y-direction is across the fiber axis, and the z-direction is through the thickness (identical to the y-direction). On ±45° bidirectionally reinforced specimens, the x and y directions are identical and oriented at 45° to either fiber direction, while the z-direction is through the thickness.
2. Thermo-Mechanical Analysis.
3. Differential Scanning Calorimetry.
4. Dynamic Mechanical Analysis.

TABLE 73

COMPARISON OF 934 AND 976 RESIN PROPERTIES[1]

RESIN	934	976
VISCOSITY, cps	6,000-12,000	6,000-12,000
*At 75 ± 0.5°C *Brookfield Model HBT Viscometer *Fiberite FTM-V-9 Test Method		
GEL TIME, MINUTES	8-16	15-30
*At 170 ± 10°C (934), 177 ± 1°C (976) *Fisher-Johns Melting Point Apparatus *Fiberite FTM-G-3 Test Method		
SPECIFIC GRAVITY OF CURED RESIN	1.30	1.28
*At 23 ± 2°C *Analytical Balance *ASTM-D-792 Test Method		
% WEIGHT LOSS	.450	.255
*RT to 200°C *T.G.A. *Heat-Up rate - - 5°C/Min		
CAST RESIN PROPERTIES		
*Tensile Strength, ksi	8,000-10,000	8,000-10,000
*Tensile Modulus, msi	.3 - .5	.3 - .5
*Tensile Elongation, %	3	5
*Mean Glass Transition Temperature, °C	214	250

[1]All data in this table provided by FIBERITE.

TABLE 74

COMPARISON OF DAY/WET MECHANICAL PROPERTIES[1]

	hy-E 1034C	hy-E 1076C
CURED LAMINATE		
Resin Content, %	24.0	25.7
Fiber Volume, %	70.0	68.6
Void Content, %	0	0
Specific Gravity	1.62	1.63
Nominal Cured Ply Thickness, In.	.005	.005
0° FLEXURAL STRENGTH, KSI (Normalized to 65% fiber volume)		
RT, Dry	273	282
RT, Wet	NT	281
250°F, Dry	NT	266
250°F, Wet	177	226
350°F, Dry	197	215
350°F, Wet	63	140
0° FLEXURAL MODULUS, MSI (Normalized to 65% fiber volume)		
RT, Dry	20.4	20.5
RT, Wet	NT	20.1
250°F, Dry	NT	19.5
250°F, Wet	19.5	20.4
350°F, Dry	20.2	19.4
350°F, Wet	10.0	18.8
SHORT BEAM SHEAR, KSI		
RT, Dry	17.7	17.1
RT, Wet	NT	14.2
250°F, Dry	12.8	12.3
250°F, Wet	6.8	8.2
350°F, Dry	7.9	10.4
350°F, Wet	4.1	5.5

[1]All data in this table provided by FIBERITE.

4.6 G-160/6535-1

This graphite/epoxy system was developed by AVCO and consists of a 160,000 filament graphite fiber tow (G-160) in a 350°F (177°C) epoxy matrix resin. Both the fiber and resin are manufactured by AVCO. The advantage of such a large filament tow is that prepreg costs can be considerably reduced.

Tables 75 through 87 present the data generated for this graphite/epoxy system. Figures 90 through 105 illustrate the stress-strain, fatigue, and creep behavior of this material as well as the effects of humidity aging upon selected composite properties.

The resin in this prepreg proved to be a very high flow material and it was difficult to avoid laminates with fiber content levels lower than 65-70% by volume, even with greatly reduced bleeder material and sealed layup bags. Although the acid digestion technique for determining fiber and resin content produced consistent fiber content levels of 65-73% by volume for the panels fabricated by several different layup schemes and cure schedules, photomicrographs of the laminate cross-sections seemed to indicate lower fiber contents for the tested laminates.

Figure 92 presents photomicrographs of two G-160/6535-1 laminates fabricated according to different layup/curing schemes and also of a T300/V378A laminate. Pertinent laminate physical property measurements are presented for each laminate along with comments based on inspection of the photomicrographs. It would appear that the fiber packings for panels K-2 and I-19 are comparable (disregarding the voids in K-2) while that for panel K-31 is slightly less (more average space between fibers). This would infer an approximately equivalent fiber content for panels K-2 and I-19 and a lower fiber content for panel K-31. As can be observed from the data accompanying the photomicrographs, this result was not obtained experimentally. Since the fiber packing obtained for panel K-31 did not appear unreasonably dense and was

comparable to that obtained for previous materials which exhibited fiber content levels of around 65%, it was decided to proceed with the cure schedule and layup scheme used for K-31 and described in Table 75 and illustrated in Figure 90 and simply report the measured fiber contents with this commentary.

TABLE 75

PROCESSING CONDITIONS FOR G-160/6535-1 COMPOSITE LAMINATES

Composite Processing Information	
Material System - G-160/6535-1 Fiber - G-160 Matrix - 6535-1 Maximum Rated Temperature - 350°F (177°C) Prepreg by - AVCO	Gr/Ep

Laminate Processing Schedule

Layup Procedure: The prepreg was stored in a closed wrapper at room temperature. Prepreg was removed from wrapper and plies cut to desired size using a razor knife. Plies were stacked in the desired sequence (release paper removed from each ply). The stack was placed in the autoclave according to the layup system illustrated in Figure 90. The corprene edge dam serves to restrict fiber flow.

Cure Schedule: Apply full vacuum and heat to 265°F in 45 $\pm$ 5 mins. under full vacuum. Hold at 265°F for 30 mins., then apply 100 psi. Heat to 350°F in 20 $\pm$5 mins. Hold at 350°F for two hours. Cool under pressure, and vacuum, to 120°F.

Postcure Schedule: The panels were placed, unrestrained, in an oven at room temperature. The oven was brought to 375°F at rate of about 5°F/min. After a four-hour hold at 375°F, the oven was turned off. When the oven was cooled to near room temperature, the panels were removed.

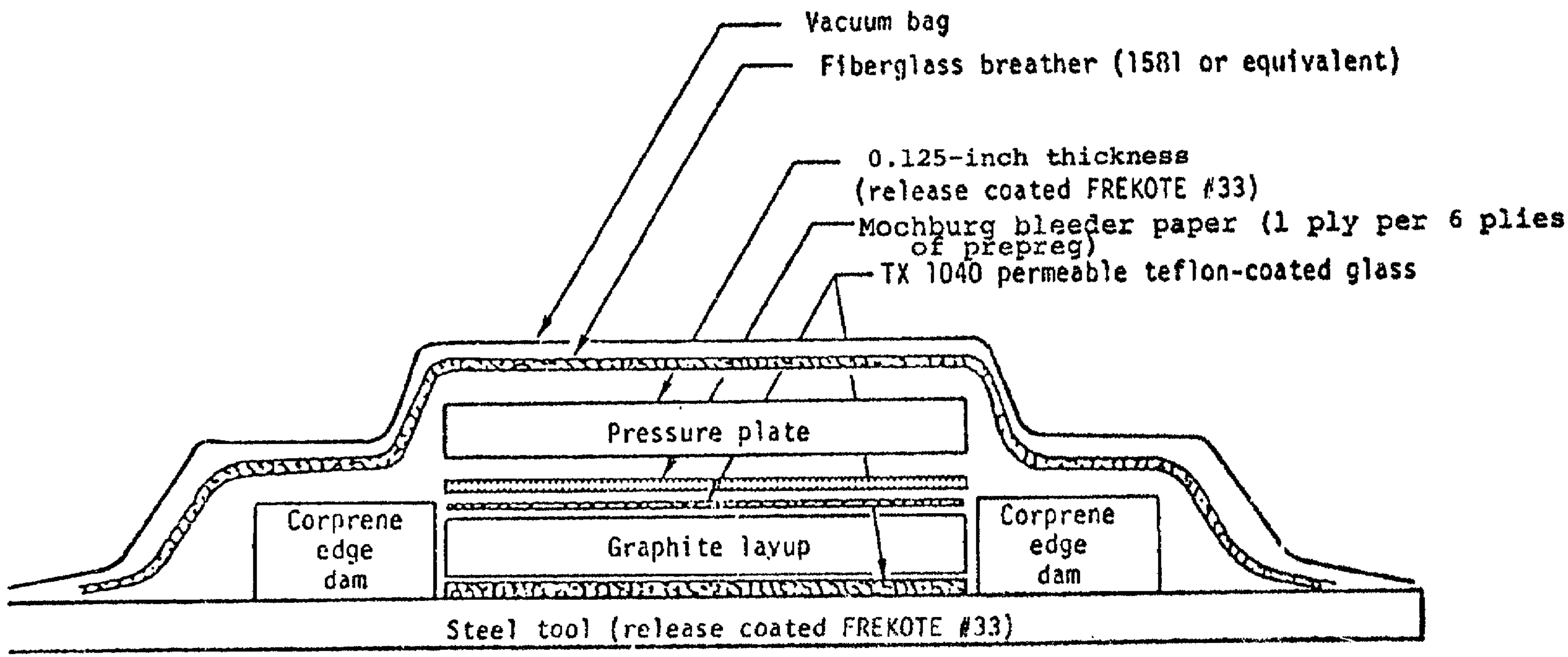


Figure 90. Layup System for AVCO 6535-1 Laminates.

TABLE 76

PREPREG AND COMPOSITE PHYSICAL PROPERTIES

Composite Physical Property Information					
Material System - G-160/6535-1 Fiber - G-160 Matrix - 6535-1 Maximum Rated Temperature - 350°F(177°C)				Gr/Ep Prepreg by - AVCO	
Prepreg Physical Properties					
(Property)		(Stnd.Dev.)	(Range)	(Test Method)	(Ref.)
Volatile Content	0.20% by wt.	0.06	0.13-0.28	QCI-C-V-14	Fiberite
Resin Content-	41.5% by wt.	1.7	39.3-44.1	R-15	Fiberite
Gel Time @ 327°F(164°C)-	38.2 min.	0.6	37.2-38.7	G-2	Fiberite
No. of Rolls Involved- 2					
No. of Batches Involved- 1					
Laminate Physical Properties[1]					
		(Stnd.Dev.)	(Range)	(Test Method)	(Ref.)
No. of Panels- 34					
Fiber Content-	68.4% by vol.	1.2	66.1-71.5	Acid Digestion	
Resin Content-	25.7% by wt.	1.0	22.9-27.3	AFML-TR-67-243	
Void Content-	≐ 0% by vol.			D2734	ASTM
Laminate Sp. Gr.-	1.61	0.01	1.59-1.63	D792	ASTM
Fiber Sp. Gr.-	1.75	As reported by manufacturer.			
Matrix Sp. Gr.-	1.26	As reported by manufacturer.			
Thickness per ply-				---	---

[1]The properties reported here represent averages for all panels of this material used throughout the program.

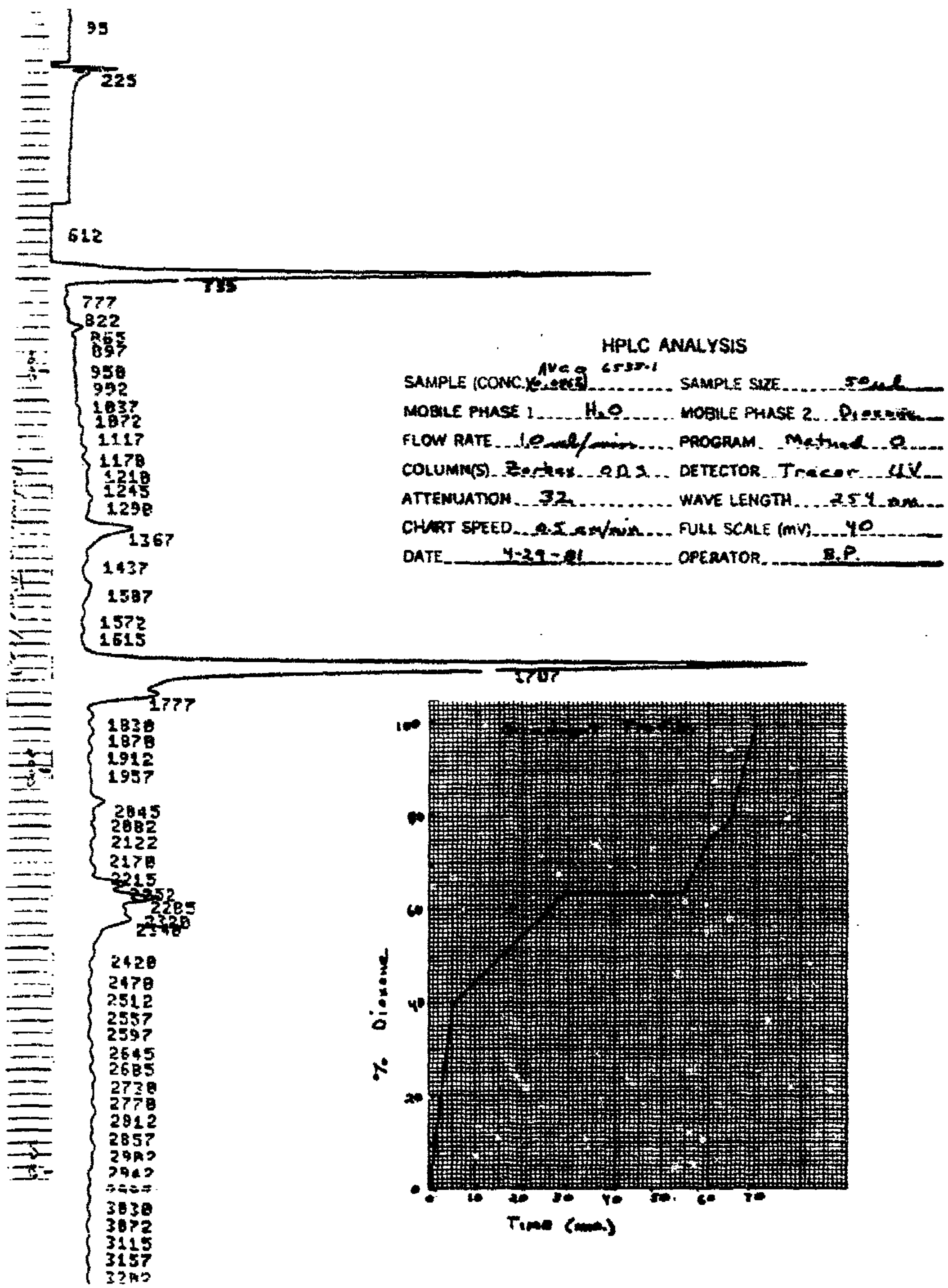
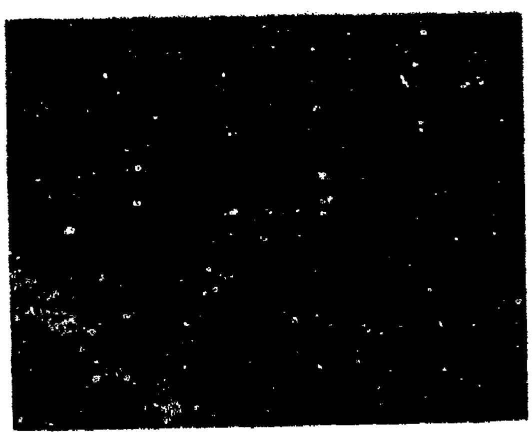


Figure 91. HPLC Analysis of AVCO 6535-1 Epoxy Resin.

(a) G-160/6535-1
PANEL K-2
EARLY CURE SCHEDULE/LAYUP SCHEME
FIBER CONTENT - 69.0% BY VOL.
SPECIFIC GRAVITY - 1.58
RESIN CONTENT - 23.8% BY WT.
VOID CONTENT - 1.2% BY VOL.
VISIBLE VOIDS



(b) G-160/6535-1
PANEL K-31
FINAL CURE SCHEDULE/LAYUP SCHEME
FIBER CONTENT - 68.5% BY VOL.
SPECIFIC GRAVITY - 1.61
RESIN CONTENT - 25.7% BY WT.
VOID CONTENT - 0
FIBER PACKING LESS DENSE THAN
FOR PANEL K 2

(c) T300/V378A
PANEL I-19
FIBER CONTENT - 65.2% BY VOL.
SPECIFIC GRAVITY - 1.59
RESIN CONTENT - 28.2% BY WT.
VOID CONTENT - 0
FIBER PACKING COMPARABLE TO
PANEL K 2

Figure 92. Photomicrographs of Composite Laminates.

TABLE 77

TENSILE PROPERTIES OF G-160/6535-1 COMPOSITE LAMINATES

Composite Material Properties

Material System - G160/6535-1	Prepreg by - AVCO
Fiber - G-160 Matrix - 6535-1	Gr/Epoxy
Maximum Rated Temperature - 350°F(177°C)	Laminate Sp. Gr. - 1.61
Resin Content - 25.7% by wt.	Nominal Ply Thickness - 0.0048 inch (0.12 mm)
Fiber Content - 68.5% by vol.	No. of panels from which specimens were tested in this table - 5
Void Content - ≈ 0% by vol.	
Thickness of each type specimen: 0° - 6 ply	; 90° - 15 ply

TENSION: 0°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{tu} [ksi](MPa)	[172.4] (1188)	[167.5] (1154)	[162.6] (1120)	[171.3] (1180)
Stnd.Dev. [ksi](MPa)	[25.7] (177)	[12.1] (83)	[7.5] (52)	[22.5] (155)
Range [ksi](MPa)	[148.3 - 213.8] (1022 - 1473)	[148.4 - 180.0] (1022 - 1240)	[150.0 - 168.6] (1033 - 1162)	[143.9 - 194.2] (991 - 1338)
No. of Specimens	5	5	5	5
F_x^{tpl} [ksi](MPa)	[172.4] (1188)	[167.5] (1154)	[162.6] (1120)	[166.7] (1149)
Stnd.Dev. [ksi](MPa)	[25.7] (177)	[12.1] (83)	[7.5] (52)	[20.7] (143)
No. of Specimens	5	5	5	5
E_x^t [Msi](GPa)	[18.49] (127)	[18.54] (128)	[21.11] (145)	[19.89] (137)
Stnd.Dev. [Msi](GPa)	[0.52] (4)	[0.64] (4.4)	[0.68] (5)	[0.82] (6)
No. of Specimens	5	5	5	5
ε_x^{tu} [μin/in](μcm/cm)	9180	8530	7820	8390
Stnd.Dev.	1410	680	940	1210
No. of Specimens	5	5	5	5
ν_{xy}^t	0.31	0.32	0.36	0.31
Stnd. Dev.	0.04	0.01	0.02	0.08
No. of Specimens	5	5	5	5
Test Method Reference	Straight-sided tension ASTM D3039			

TENSION: 90°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_y^{tu} [ksi](MPa)	[4.93] (34)	[5.51] (38)	[3.88] (27)	[3.49] (24)
Stnd.Dev. [ksi](MPa)	[0.54] (4)	[0.43] (3)	[0.53] (4)	[0.85] (6)
Range	[4.30 - 5.43] (30 - 37)	[5.19 - 6.15] (36 - 42)	[3.09 - 4.43] (21 - 31)	[2.42 - 4.41] (17 - 30)
No. of Specimens	5	4	5	4
F_y^{tpl} [ksi](MPa)	[1.58] (11)	[5.51] (38)	[2.70] (19)	[2.42] (17)
Stnd.Dev. [ksi](MPa)	[0.35] (2)	[0.43] (3)	[1.74] (12)	[0.64] (4)
No. of Specimens	5	4	5	4
E_y^t [Msi](GPa)	[2.27] (16)	[1.82] (13)	[1.59] (11)	[1.63] (11)
Stnd.Dev. [Msi](GPa)	[0.31] (2)	[0.27] (2)	[0.21] (1.4)	[0.11] (1)
No. of Specimens	5	5	5	4
ε_y^{tu} [μin/in](μcm/cm)	2290	3290	2490	2270
Stnd. Dev.	510	440	380	780
No. of Specimens	5	4	5	4
ν_{yx}^t	0.038[1]	0.031[1]	0.027[1]	0.025[1]
Stnd. Dev.	---	---	---	---
No. of Specimens	---	---	---	---
Test Method Reference	Straight-sided tension ASTM D3039			

[1] Computed using elastic moduli and longitudinal Poisson's ratio.

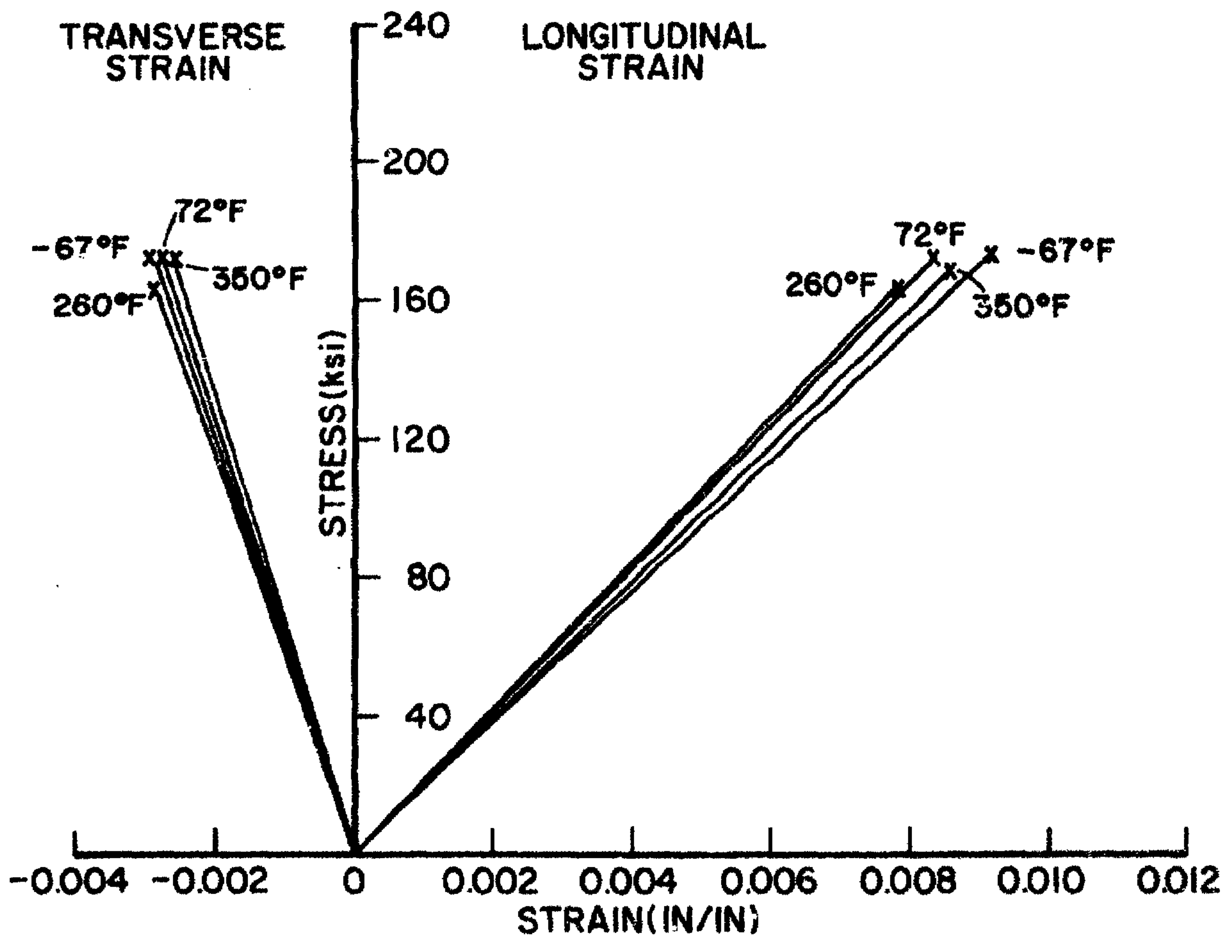


Figure 93. Tensile Stress-Strain Curves for Unidirectional G-160/6535-1 Composite Laminates: 0° Fiber Orientation.

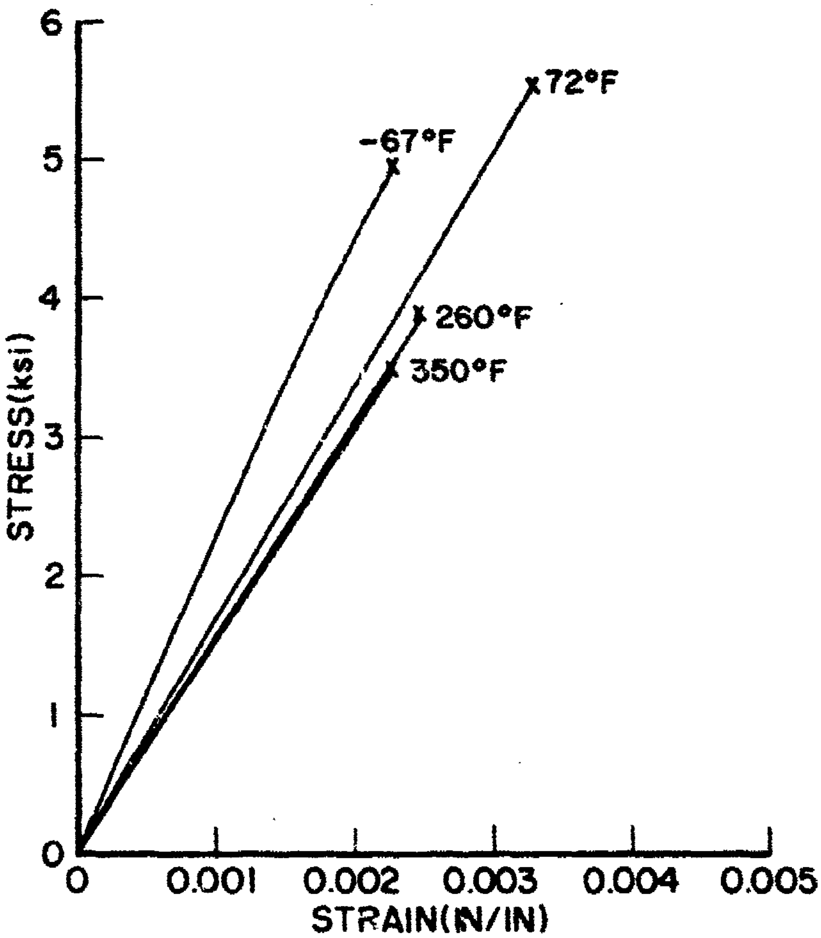


Figure 94. Tensile Stress-Strain Curves for Unidirectional G-160/6535-1 Composite Laminates: 90° Fiber Orientation.

TABLE 73

TENSILE PROPERTIES OF G-160/6535-1 COMPOSITE LAMINATES

Composite Material Properties

Material System - G-160/6535-1	**Prepreg by** - AVCO — Gr/Epoxy
Fiber - G-160 Matrix - 6535-1	**Laminate Sp. Gr.** - 1.61
Maximum Rated Temperature - 350°F(177°C)	**Nominal Ply Thickness** - 0.0049 inch(0.13 mm)
Resin Content - 26.0% by wt.	No. of panels from which specimens were tested in this table - 3
Fiber Content - 67.7% by vol.	Thickness of specimen - 8 plies
Void Content - ≤ 0% by vol.	

TENSION: ±45°

	-67°F(-55°C)	72°F(22°C)	250°F (127°C)	350°F (177°C)
F_x^{tu} [ksi](MPa)	[19.43] (134)	[16.53] (114)	[15.56] (107)	[16.48] (114)
Stnd.Dev.[ksi](MPa)	[0.90] (6)	[1.17] (8)	[0.41] (3)	[1.10] (8)
Range [ksi](MPa)	[18.72-20.89] (129 - 144)	[15.36-17.77] (106 - 122)	[14.88-15.91] (103 - 110)	[15.03-17.48] (104 - 120)
No. of Specimens	5	5	5	5
F_x^{tpl} [ksi](MPa)	[9.53] (66)	[5.92] (41)	[4.61] (32)	[4.05] (28)
Stnd.Dev.[ksi](MPa)	[1.96] (14)	[1.41] (10)	[0.72] (5)	[0.28] (2)
No. of Specimens	5	5	5	5
E_x^t [Msi](GPa)	[3.28] (23)	[3.12] (21)	[3.05] (21)	[2.79] (19)
Stnd.Dev.[Msi](GPa)	[0.21] (1)	[0.12] (1)	[0.12] (1)	[0.08] (0.6)
No. of Specimens	5	5	5	5
ε_x^{tu} [μin/in](μcm/cm)	6,890	6,940	1[illegible],520	34,800
Stnd. Dev.	1,380	850	2,150	--
No. of Specimens	5	5	5	2^1
ν_{xy}^t	0.62	0.65	0.72	0.72
Stnd. Dev.	0.04	0.05	0.07	0.03
No. of Specimens	5	5	5	5
Test Method Reference	Straight-sided tension ASTM D3039			

[1]Strain gage failed before end of test on three specimens.

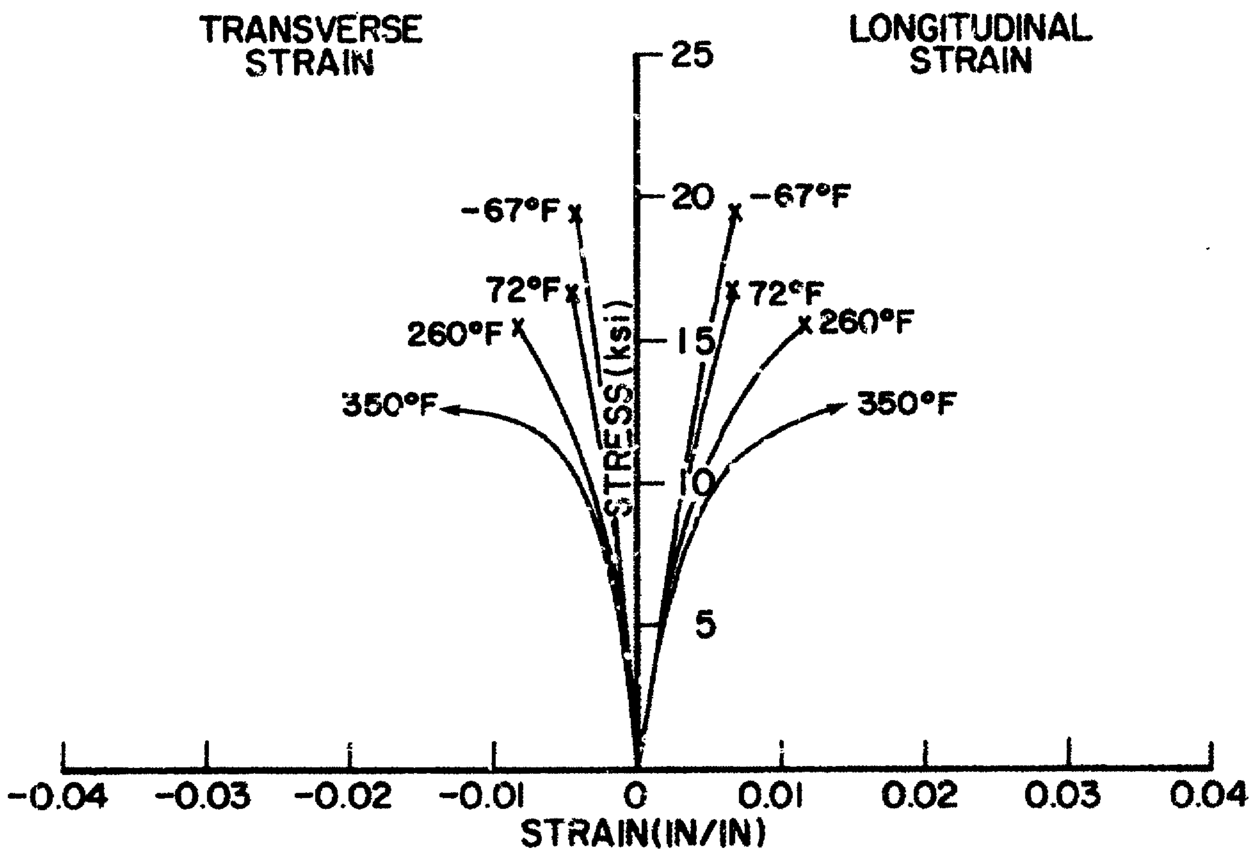


Figure 95. Tensile Stress-Strain Curves for Bidirectional G-160/6535-1 Composite Laminates: ±45° Fiber Orientation.

TABLE 79

TENSILE PROPERTIES OF G-160/6535-1 COMPOSITE LAMINATES

Composite Material Properties

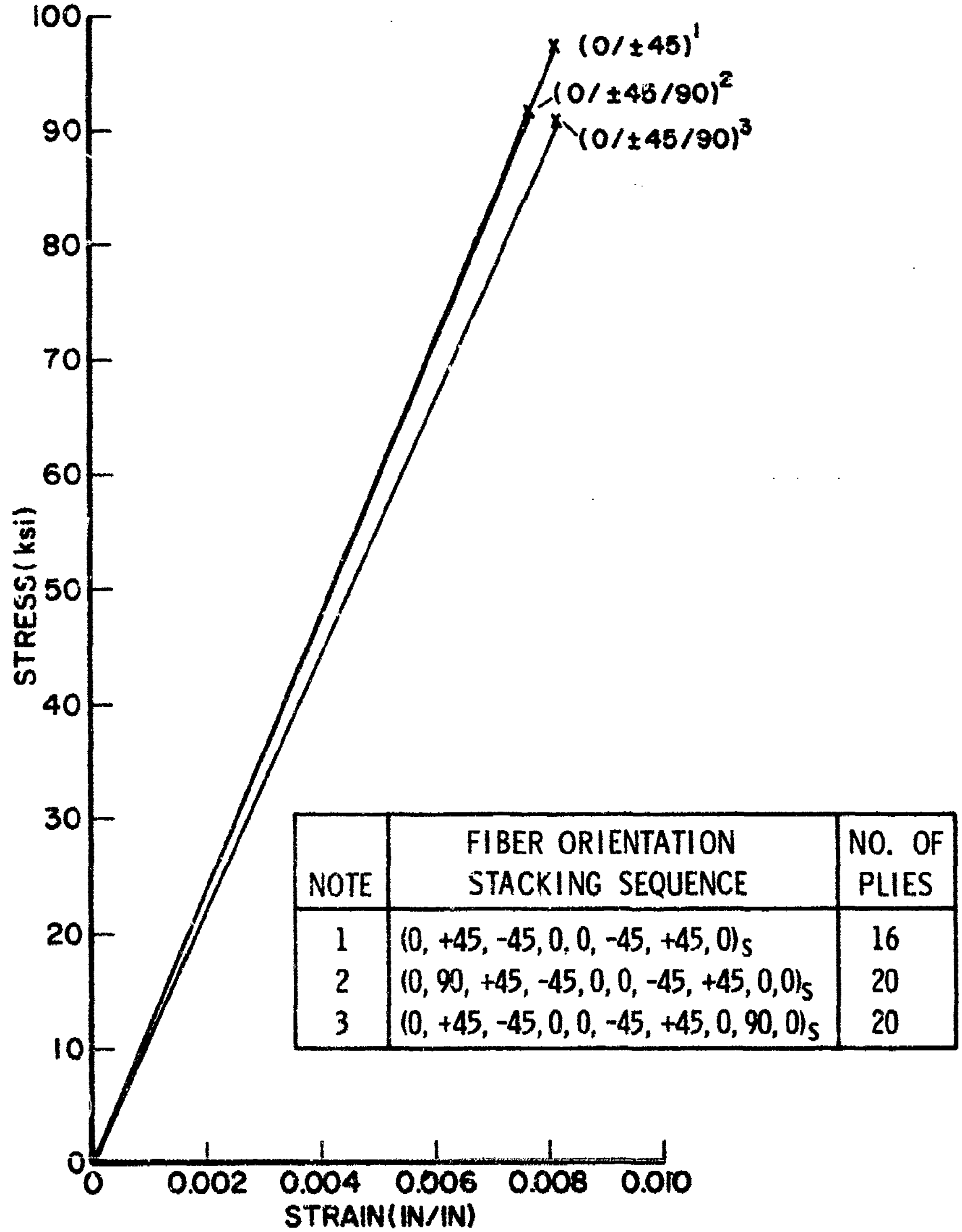
Material System - G-160/6535-1 Fiber - G-160 Matrix - 6535-1 Maximum Rated Temperature - 350°F(177°C) Resin Content - N.A. Fiber Content - N.A. Void Content - N.A.	Prepreg by - AVCO Laminate Sp. Gr. - N.A. Nominal Ply Thickness -0.0048 inch (0.12 mm) No. of panels from which specimens were tested in this table - 9 Thickness of specimen - (see footnotes)

Gr/Epoxy

TENSION: 72°F (22°C)

	(0/±45)[1]	(0/±45/90)[2]	(0/±45/90)[3]
F_x^{tu} [ksi] (MPa)	[97.3] (670)	[91.5] (630)	[90.9] (626)
Stnd. Dev. [ksi] (MPa)	[6.0] (41)	[8.8] (61)	[6.0] (41)
Range [ksi] (MPa)	[88.3 - 103.2] (608 - 711)	[79.9 - 102.0] (551 - 703)	[84.8 - 100.7] (584 - 694)
No. of Specimens	5	5	5
F_x^{tpl} [ksi] (MPa)	[97.3] (670)	[91.5] (630)	[90.9] (626)
Stnd. Dev. [ksi] (MPa)	[6.0] (41)	[8.8] (61)	[6.0] (41)
No. of Specimens	5	5	5
E_x^t [Msi] (GPa)	[11.41] (79)	[11.59] (80)	[10.92] (75)
Stnd. Dev. [Msi] (GPa)	[1.11] (8)	[0.67] (5)	[0.12] (1)
No. of Specimens	5	5	5
ϵ_x^{tu} [µin/in] (µcm/cm)	8170	7740	8210
Stnd. Dev.	680	720	560
No. of Specimens	5	5	5
ν_{xy}^t	0.62	0.41	0.37
Stnd. Dev.	0.04	0.02	0.02
No. of Specimens	5	5	5
Test Method Reference	Straight-sided tension ASTM D3039		

[1] $(0,+45,-45,0,0,-45,+45,0)_s$ - 16 ply.
[2] $(0,90,+45,-45,0,0,-45,+45,0,0)_s$ - 20 ply.
[3] $(0,+45,-45,0,0,-45,+45,0,90,0)_s$ - 20 ply.



NOTE	FIBER ORIENTATION STACKING SEQUENCE	NO. OF PLIES
1	$(0, +45, -45, 0, 0, -45, +45, 0)_S$	16
2	$(0, 90, +45, -45, 0, 0, -45, +45, 0, 0)_S$	20
3	$(0, +45, -45, 0, 0, -45, +45, 0, 90, 0)_S$	20

Figure 96. Tensile Stress-Strain Curves for Multidirectional G-160/6535-1 Composite Laminates.

TABLE 80

COMPRESSIVE PROPERTIES OF G-160/6535-1 COMPOSITE LAMINATES

Composite Material Properties				
Material System - G-160/6535-1 Fiber - G-160 Matrix - 6535-1 Maximum Rated Temperature - 350°F(177°C) Resin Content - 23.9% by wt. Fiber Content - 70.0% by vol. Void Content - ≐ 0% by vol. Thickness of each type specimen: 0° - 21 ply; 90° - 21 ply	Prepreg by - AVCO Laminate Sp. Gr. - 1.61 Nominal Ply Thickness - 0.0047 in. (0.12 mm) No. of panels from which specimens were tested in this table - 3	Gr/Epoxy		
COMPRESSION: 0°				
	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{cu} [ksi](MPa)	[214.0] (1474)	[212.3] (1463)	[188.8](1301)	[151.4](1043)
Stnd.Dev. [ksi](MPa)	[19.1] (132)	[8.0] (55)	[20.1](138)	[11.3] (78)
Range [ksi](MPa)	[192.4 - 235.4] (1326 - 1622)	[204.0 - 223.9] (1405 - 1543)	[156.5 - 206.3] (1078 - 1421)	[145.8 - 163.0] (1005 - 1123)
No. of Specimens	5	5	5	5
F_x^{cpl} [ksi](MPa)	[73.9] (509)	[106.3] (732)	[80.9] (557)	[101.9] (703)
Stnd.Dev. [ksi](MPa)	[8.6] (59)	[33.2] (229)	[13.1] (90)	[23.2] (160)
No. of Specimens	5	5	3	5
E_x^c [Msi](GPa)	[20.54] (142)	[19.21] (132)	[18.73] (129)	[21.40] (147)
Stnd.Dev. [Msi](GPa)	[1.06] (7)	[1.34] (9)	[1.53] (11)	[2.45] (17)
No. of Specimens	5	5	5	5
ε_x^{cu} [μin/in](μcm/cm)	9,520+[1,2]	14,800+[1,3]	11,060+[1,4]	8,530
Stnd. Dev.	2,200	3,890	1,850	1,030
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3410			
COMPRESSION: 90°				
F_y^{cu} [ksi](MPa)	[36.1] (249)	[27.0] (180)	[24.0] (165)	[19.8] (136)
Stnd.Dev. [ksi](MPa)	[6.3] (43)	[3.3] (23)	[1.3] (9)	[3.9] (27)
Range	[29.7 - 45.5] (205 - 313)	[22.6 - 30.2] (156 - 208)	[22.0 - 25.4] (152 - 175)	[16.6 - 26.3] (114 - 181)
No. of Specimens	5	5	5	5
F_y^{cpl} [ksi](MPa)	[14.1] (786)	[13.2] (91)	[15.9] (110)	[11.4] (79)
Stnd.Dev. [ksi](MPa)	[4.0] (28)	[1.5] (10)	[2.8] (19)	[1.9] (13)
No. of Specimens	5	5	5	5
E_y^c [Msi](GPa)	[2.01] (14)	[2.04] (14)	[1.40] (10)	[1.80] (12)
Stnd.Dev. [Msi](GPa)	[0.16] (1)	[0.4] (3)	[0.11] (1)	[0.40] (3)
No. of Specimens	5	5	5	5
ε_y^{cu} [μin/in](μcm/cm)	25,730+[1,2]	21,960+[1,4]	15,660+[1,5]	11,750+[1,5]
Stnd. Dev.	5,330	13,350	6,100	4,490
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3410			

[1] Ultimate strain value represents maximum observed values rather than ultimate values.
[2] Three specimens exhibited evidence of buckling.
[3] One specimen exhibited evidence of buckling.
[4] Two specimens exhibited evidence of buckling.
[5] Four specimens exhibited evidence of buckling.

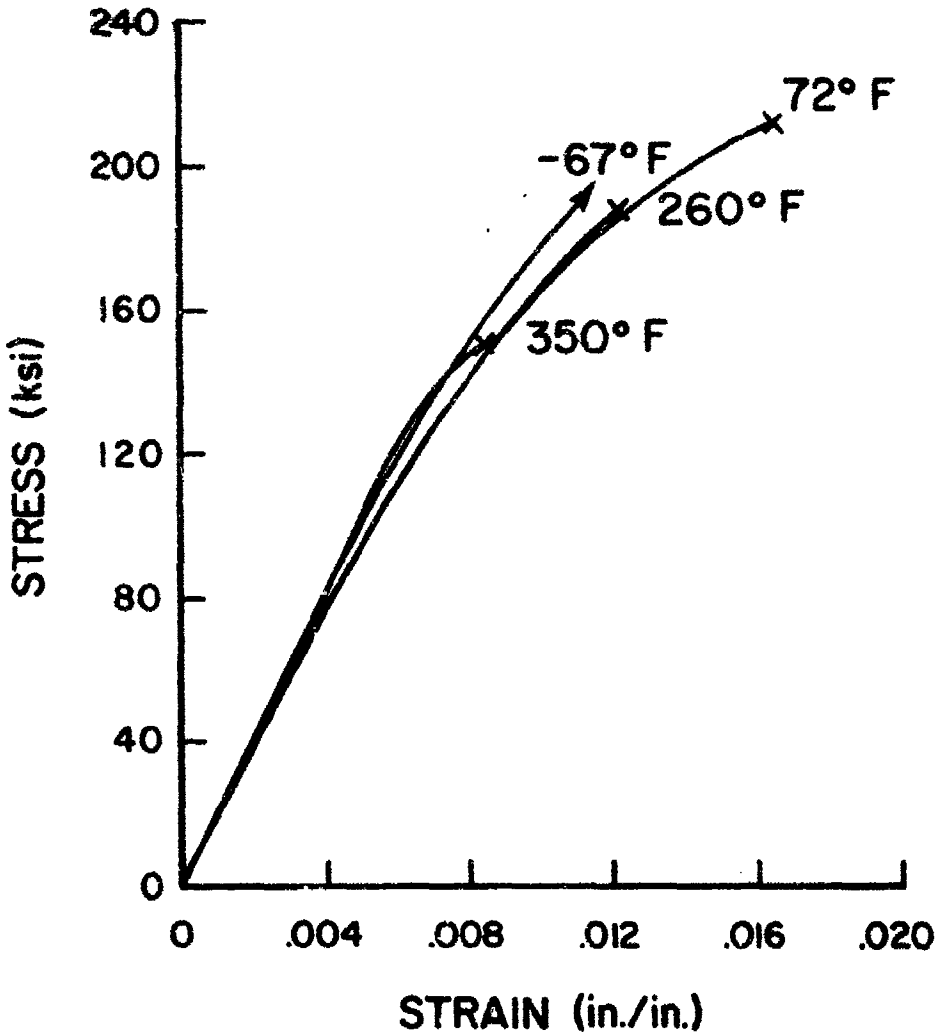


Figure 97. Compressive Stress-Strain Curves for Unidirectional G-160/6535-1 Composite Laminates: 0° Fiber Orientation.

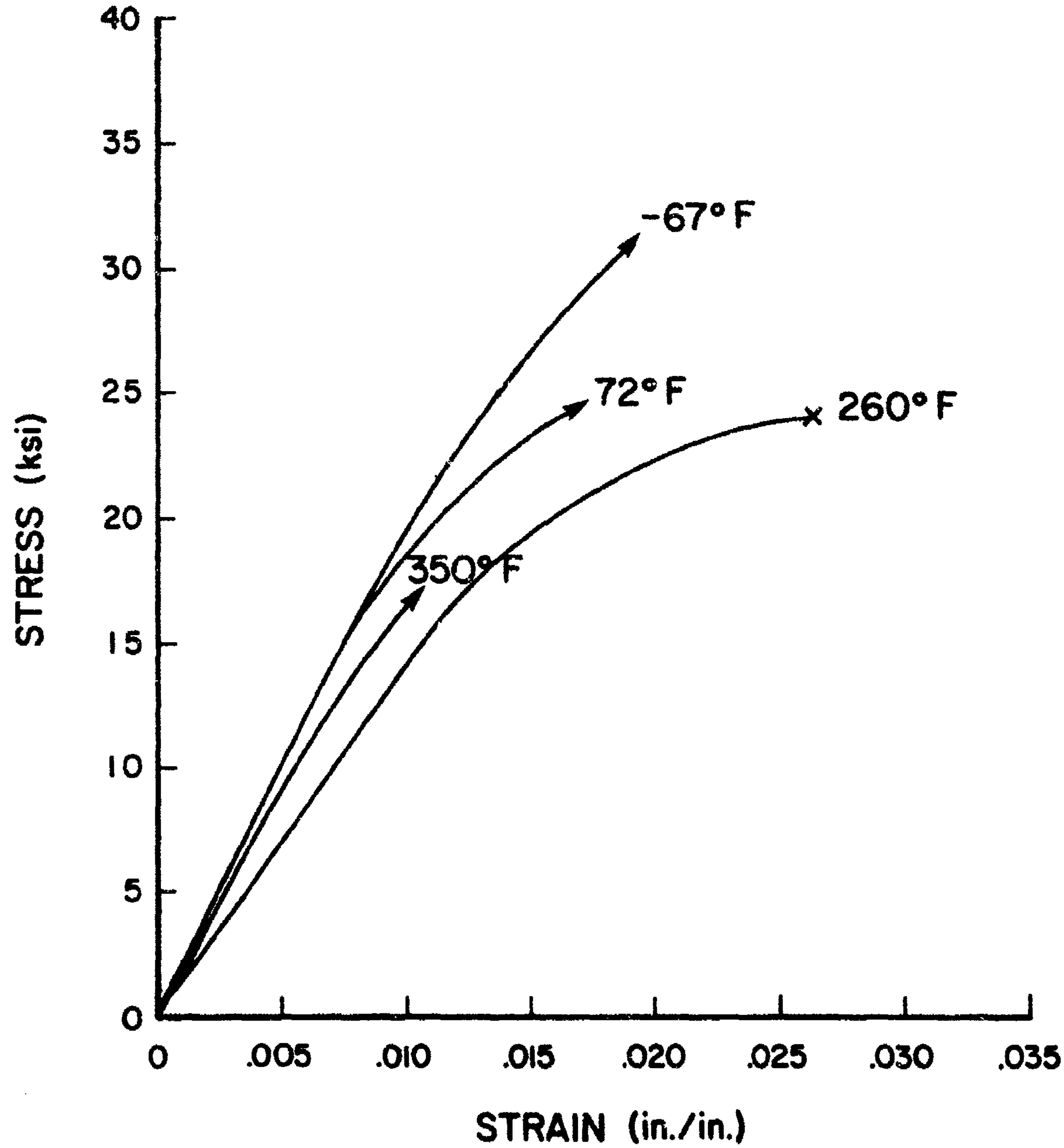


Figure 98 . Compressive Stress-Strain Curves for Unidirectional G-160/6535-1 Composite Laminates: 90° Fiber Orientation.

TABLE 81

FLEXURAL PROPERTIES OF G-160/6535-1 COMPOSITE LAMINATES

Composite Material Properties

Material System - G-160/6535-1	Prepreg by - AVCO	Gr/Epoxy
Fiber - G-160 Matrix - 6535-1		
Maximum Rated Temperature - 350°F(177°C)	Laminate Sp. Gr. - 1.61	
Resin Content - 24.8% by wt.	Nominal Ply Thickness - 0.0047 inch(0.12 mm)	
Fiber Content - 69.6% by vol.	No. of panels from which specimens were tested in this table - 2	
Void Content - ≐ 0% by vol.		
Thickness of each type specimen: 0° - 14 ply ; 90° - 14 ply		

FLEXURE: 0°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_x^{fu} [ksi](MPa)	[239.9] (1653)	[231.3] (1594)	[219.7] (1514)	[181.7] (1252)
Stnd.Dev. [ksi](MPa)	[17.2] (118)	[9.4] (65)	[4.9] (34)	[5.9] (53)
Range [ksi](MPa)	[212.3 - 255.9] (1463 - 1763)	[215.2 - 237.6] (1483 - 1637)	[214.2 - 223.5] (1476 - 1540)	[175.8 - 189.4] (1211 - 1305)
No. of Specimens	5	5	3[1]	5
E_x^f [Msi](GPa)	[19.04] (131)	[18.49] (127)	[18.01] (124)	[16.85] (1150)
Stnd.Dev. [Msi](GPa)	[1.19] (8)	[0.96] (7)	[0.60] (4)	[0.61] (4)
No. of Specimens	5	5	3	5
Test Method	3 pt.	4 pt.	3 pt.	3 pt.
Reference	Design Guide, Jan. 1971 - Corresponds to ASTM D790 except for loading points and loading speed.			

FLEXURE: 90°

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F_y^{fu} [ksi](MPa)	[9.11] (63)	[8.86] (61)	[6.40] (44)	[6.50] (45)
Stnd.Dev. [ksi](MPa)	[1.75] (12)	[0.44] (3)	[0.47] (3)	[0.22] (2)
Range [ksi](MPa)	[7.09 - 10.14] (49 - 70)	[8.41 - 9.29] (58 - 64)	[4.70 - 7.78] (32 - 54)	[6.32 - 7.56] (44 - 52)
No. of Specimens	5	5	5	5
E_y^f [Msi](GPa)	[1.53] (11)	[1.45] (10)	[1.45] (10)	[1.34] (9)
Stnd.Dev. [Msi](GPa)	[0.04] (0.3)	[0.06] (0.4)	[0.04] (0.3)	[0.13] (1)
No. of Specimens	5	5	5	5
Test Method	4 pt. flexure } corresponds to ASTM D790 except for loading			
Reference	Design Guide, Jan. 1971 } points and loading speed			

[1] Two specimens tested in 4-point loading exhibited shear failure at a flexural stress of 163.7 ksi.

TABLE 82

SHEAR PROPERTIES OF G-160/6535-1 COMPOSITE LAMINATES

Composite Material Properties

Material System - G-160/6535-1 | Prepreg by - AVCO | Gr/Epoxy

Fiber - G-160 | Matrix - 6535-1

Maximum Rated Temperature - 350°F (177°C)

Resin Content - 26.7% by wt.

Fiber Content - 66.9% by vol.

Void Content - ≐ 0% by vol.

Laminate Sp. Gr. - 1.60

Nominal Ply Thickness - 0.0050 inch (0.13 mm)

No. of panels from which specimens were tested in this table - 9

Thickness of each type specimen - Inplane - 8 ply ; Interlaminar - 15 ply

INPLANE SHEAR

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F^{su}_{xy} [ksi] (MPa)	[9.71] (67)	[8.43] (58)	[7.77] (54)	[8.24] (57)
Stnd.Dev. [ksi] (MPa)	[0.45] (3)	[0.67] (5)	[0.21] (1)	[0.55] (4)
Range [ksi] (MPa)	[9.34 - 10.44] (64 - 72)	[7.68 - 9.00] (53 - 62)	[7.42 - 7.94] (51 - 55)	[7.54 - 8.74] (52 - 60)
No. of Specimens	5	5	5	5
G^{s}_{xy} [Msi] (GPa)	[1.01] (7)	[0.94] (6)	[0.89] (6)	[0.81] (6)
Stnd.Dev. [Msi] (GPa)	[0.06] (0.4)	[0.03] (0.2)	[0.05] (0.3)	[0.03] (0.2)
No. of Specimens	5	5	5	5
Test Method Reference	ASTM D3518			

INTERLAMINAR SHEAR

	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)
F^{isu} [ksi] (MPa)	[16.96] (117)	[14.53] (100)	[11.90] (82)	[9.27] (64)
Stnd.Dev. [ksi] (MPa)	[1.14] (8)	[1.17] (8)	[0.47] (3)	[0.62] (4)
Range	[15.19 - 18.21] (105 - 125)	[13.10 - 16.13] (90 - 111)	[11.36 - 12.39] (78 - 85)	[8.46 - 9.79] (58 - 67)
No. of Specimens	5	10	5	5
Test Method Reference	Short beam shear ASTM D2344			

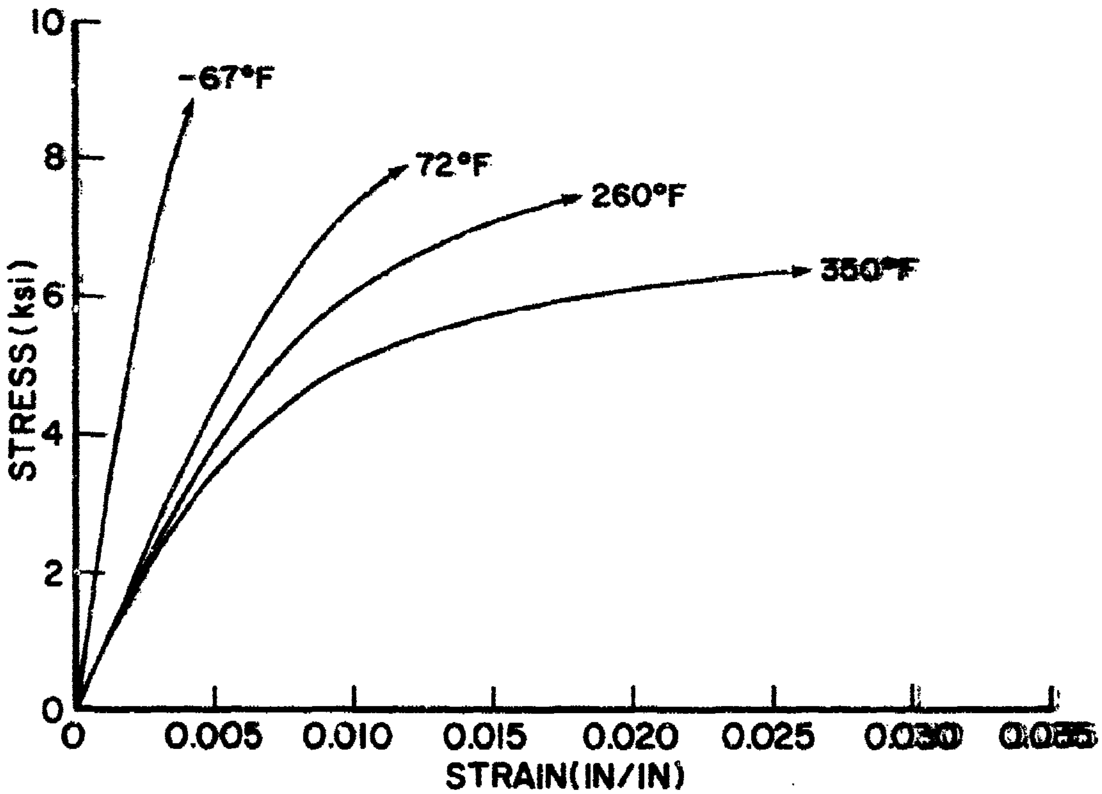


Figure 99. Inplane Shear Stress-Strain Curves for G-160/6535-1 Composite Laminates.

TABLE 83

TENSILE, COMPRESSIVE, AND SHEAR PROPERTIES OF G-160/6535-1 COMPOSITE LAMINATES AFTER HUMIDITY AGING

Composite Material Properties

Material System - G-160/6535-1
Fiber - G-160 Matrix - 6535-1
Maximum Rated Temperature - 350°F
Resin Content - 25.4% by wt.(177°C)
Fiber Content - 68.5% by vol.
Void Content - 4.0%
Thickness of each type specimen: Tension - 15 ply; Compr. - 20 ply; Shear - 15 ply

Prepreg by - AVCO
Laminate Sp. Gr. - 1.61
Nominal Ply Thickness - 0.0049 in.(0.12mm)
No. of panels from which specimens were tested in this table - 8
Aging Conditions - 160°F(71°C) & 100% RH

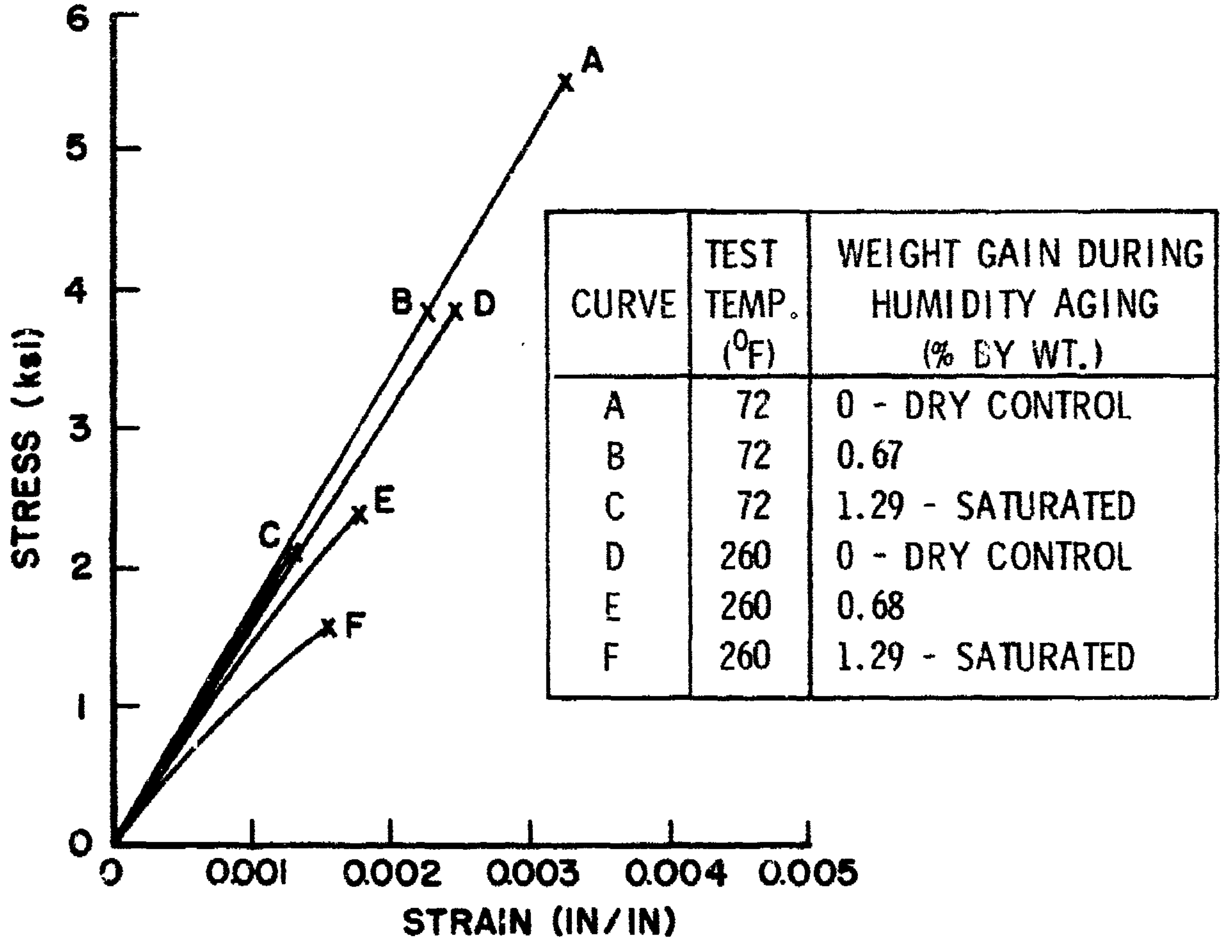
Gr/Epoxy

TENSION: 90°	72°F(22°C)	260°F(127°C)	72°F(22°C)	260°F(127°C)
Exposure Time (hrs)	216	216	3388	3388
Wt. Gain(% of orig. dry wt.)	0.67	0.68	1.29	1.29
Stnd. Dev.(%)	0.02	0.02	0.01	0.01
No. of Specimens	5	5	5	5
F_y^{tu} [ksi](MPa)	[3.84] (26)	[2.41] (17)	[2.18] (15)	[1.59] (11)
Stnd. Dev. [ksi](MPa)	[0.33] (2)	[0.29] (2)	[0.34] (2)	[0.06] (0.4)
Range [ksi](MPa)	[3.32-4.14] (23 - 29)	[1.93-2.62] (13 - 18)	[1.72-2.56] (12 - 18)	[1.52-1.67] (10 - 12)
No. of Specimens	5	5	5	5
F_y^{tpl} [ksi](MPa)	[3.84] (26)	[1.71] (12)	[2.18] (15)	[0.58] (4)
Stnd. Dev. [ksi](MPa)	[0.33] (2)	[0.26] (2)	[0.34] (2)	[0.11] (1)
No. of Specimens	5	5	5	5
E_y^t [Msi](GPa)	[1.69] (12)	[1.45] (10)	[1.65] (11)	[1.24] (9)
Stnd. Dev. [Msi](GPa)	[0.11] (1)	[0.28] (2)	[0.16] (1)	[0.13] (1)
No. of Specimens	5	5	5	5
ϵ_y^{tu} [μin/in](μcm/cm)	2280	1800	1320	1570
Stnd. Dev.	170	430	150	150
No. of Specimens	5	5	5	5
Test Method Reference	Straight-sided tension ASTM D3039			

COMPRESSION: 90°	72°F(22°C)	260°F(127°C)	72°F(22°C)	260°F(127°C)
Exposure Time(hrs)	166.5	166.5	1532	1621
Wt. Gain(% of orig. dry wt.)	0.62	0.63	1.22	1.27
Stnd. Dev. (%)	0.02	0.02	0.01	0.02
No. of Specimens	5	5	5	5
F_y^{cu} [ksi](MPa)	[28.78] (198)	[20.58] (142)	[27.35] (188)	[17.34] (119)
Stnd. Dev. [ksi](MPa)	[1.84] (13)	[1.48] (10)	[2.73] (19)	[1.16] (8)
Range	[25.85-30.65] (178 - 211)	[18.37-22.33] (127 - 154)	[23.28-29.04] (160 - 200)	[16.17-18.74] (111 - 129)
No. of Specimens	5	5	5	5
F_y^{cpl} [ksi](MPa)	[9.07] (62)	[6.59] (45)	[11.96] (82)	[3.32] (23)
Stnd. Dev. [ksi](MPa)	[5.07] (35)	[1.50] (10)	[3.57] (25)	[0.67] (5)
No. of Specimens	5	5	5	5
E_y^c [Msi](GPa)	[1.81] (12)	[1.41] (10)	[1.62] (11)	[1.61] (11)
Stnd. Dev. [Msi](GPa)	[0.06] (0.4)	[0.13] (1)	[0.13] (1)	[0.08] (1)
No. of Specimens	4	5	5	5
ϵ_y^{cu} [μin/in](μcm/cm)	22,980[1]	29,180[1]	26,640	26,740[1]
Stnd. Dev.	5,510	12,070	5,000	8,710
No. of Specimens	5	5	4	5
Test Method Reference	ASTM D3410			

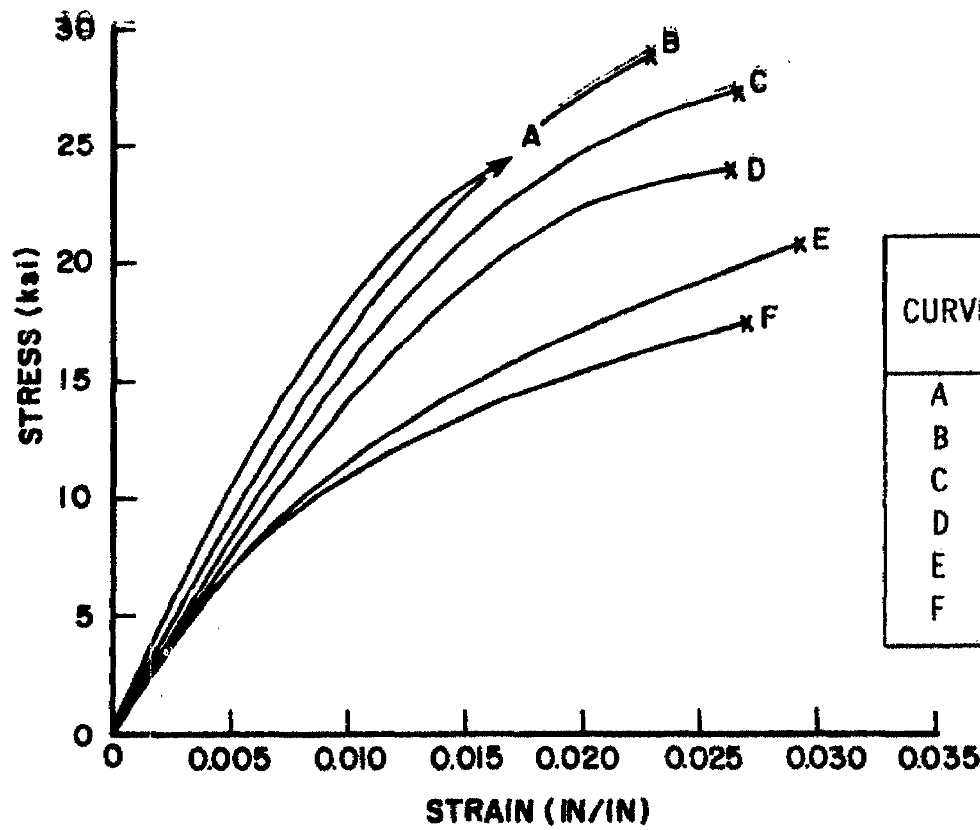
INTERLAMINAR SHEAR	72°F(22°C)	260°F(127°C)	72°F(22°C)	260°F(127°C)
Exposure Time(hrs)	91	91	1,530	1,530
Wt. Gain(% of orig. dry wt.)	0.55	0.56	1.15	1.13
Stnd. Dev. (%)	0.08	0.07	0.15	0.11
No. of Specimens	10	5	10	5
F^{isu} [ksi](MPa)	[14.26] (98)	[9.28] (64)	[12.33] (85)	[6.51] (45)
Stnd. Dev. [ksi](MPa)	[0.52] [illegible]	[0.60] (4)	[0.73] (5)	[0.14] (1)
Range [ksi](MPa)	[13.56-15.08] (93 - 104)	[8.40-9.84] (58 - 68)	[10.99-13.28] (76 - 91)	[6.28-6.62] (43 - 46)
No. of Specimens	10	5	10	5
Test Method Reference	ASTM D2344			

[1]One specimen exhibited evidence of buckling.



CURVE	TEST TEMP. (°F)	WEIGHT GAIN DURING HUMIDITY AGING (% BY WT.)
A	72	0 - DRY CONTROL
B	72	0.67
C	72	1.29 - SATURATED
D	260	0 - DRY CONTROL
E	260	0.68
F	260	1.29 - SATURATED

Figure 100. Tensile Stress-Strain Curves for Unidirectional G-160/6535-1 Composite Laminates After Humidity Aging: 90° Fiber Orientation.



CURVE	TEST TEMP. (^0F)	WEIGHT GAIN DURING HUMIDITY AGING (% BY WT.)
A	72	0 - DRY CONTROL
B	72	0.62
C	72	1.22 - SATURATED
D	260	0 - DRY CONTROL
E	260	0.63
F	260	1.27 - SATURATED

Figure 101. Compressive Stress-Strain Curves for Unidirectional Composite Laminates After Humidity Aging: 90° Fiber Orientation.

TABLE 84

CREEP PROPERTIES OF G-160/6535-1 COMPOSITE LAMINATES

Composite Material Properties

Material System - G-160/6535-1 Fiber - G-160 Matrix - 6535-1 Maximum Temperature Rating - 350°F(177°C) Resin Content - 26.2% by wt. Fiber Content - 67.8% by vol. Void Content - ≐ 0% by vol. Test Method - Straight-sided tension Reference - ASTM D2290 and D3039	Prepreg by - AVCO Laminate Sp. Gr. - 1.61 Nominal Ply Thickness - 0.0048 inch(0.12 mm) No. of panels from which specimens were tested in this table - 18 Thickness of each type specimen: ±45° - 8 ply 0/±45/90[2] - 20 ply 0/±45°[1] - 16 ply 0/±45/90[3] - 20 ply	Gr/Ep

CREEP

Temperature	Fiber Orientation	±45°	0/±45[1]	0/±45/90[2]	0/±45/90[3]
72°F(22°C)	Stress Level[ksi](MPa)	[13.22](91)	[73.22](504)	[72.70](501)	[77.83](536)
	Creep Strain, 500 hr(%)	0.2497	0.0073	0.0164	0.0102
	No. of Specimens	3	2[6]	2[6]	2[6]
	Residual Strength[ksi](MPa)	[18.17](125)	[108.40](747)	[109.84](757)	[113.85](784)
	No. of Specimens	3	2	2	2
	Stress Level[ksi](MPa)	[11.57](80)	[64.07](441)	[63.62](438)	[68.10](469)
	Creep Strain, 500 hr(%)	0.2031	0.0171	0.0148	0.0122
	No. of Specimens	3	3	3	3
	Residual Strength[ksi](MPa)	[19.30](133)	[103.46](713)	[112.20](773)	[107.24](739)
	No. of Specimens	3	3	3	3
	Stress Level[ksi](MPa)	[9.92](68)			
	Creep Strain, 500 hr(%)	0.1124			
	No. of Specimens	3			
	Residual Strength[ksi](MPa)	[19.24](133			
	No. of Specimens	3			
260°F(127°C)	Stress Level[ksi](MPa)	[12.45](86)			
	Creep Strain, 500 hr(%)	---[4]			
	No. of Specimens	3			
	Residual Strength[ksi](MPa)	[14.68](101)			
	No. of Specimens	2[6]			
	Stress Level[ksi](MPa)	[10.89](75)			
	Creep Strain, 500 hr(%)	3424[5]			
	No. of Specimens	2			
	Residual Strength[ksi](MPa)	[16.39](113			
	No. of Specimens	2[6]			
	Stress Level[ksi](MPa)	[9.44](65)			
	Creep Strain, 500 hr(%)	0.2520			
	No. of Specimens	3			
	Residual Strength[ksi](MPa)	[16.25](112)			
	No. of Specimens	3			
350°F(177°C)	Stress Level[ksi](MPa)	[11.54](80)			
	Creep Strain, 500 hr(%)	1.9939			
	No. of Specimens	1[5]			
	Residual Strength[ksi](MPa)	[16.01](110)			
	No. of Specimens	3			
	Stress Level[ksi](MPa)	[9.89](68)			
	Creep Strain, 500 hr(%)	2.3224			
	No. of Specimens	1[5]			
	Residual Strength[ksi](MPa)	[17.01](117)			
	No. of Specimens	3			
	Stress Level[ksi](MPa)	[8.24](57)			
	Creep Strain, 500 hr(%)	1.7352			
	No. of Specimens	1[6,7]			
	Residual Strength[ksi](MPa)	[15.88](109			
	No. of Specimens	1			

[1] $(0,45,-45,0,0,-45,45,0)_s$-16 ply
[2] $(0,45,-45,0,0,-45,45,0,90,0)_s$-20 ply
[3] $(0,90,45,-45,0,0,-45,45,0,0)_s$-20 ply
[4] Strain gages failed on three specimens during test.
[5] Strain gages failed on two specimens during test.
[6] One specimen failed during test.
[7] One specimen overheated.

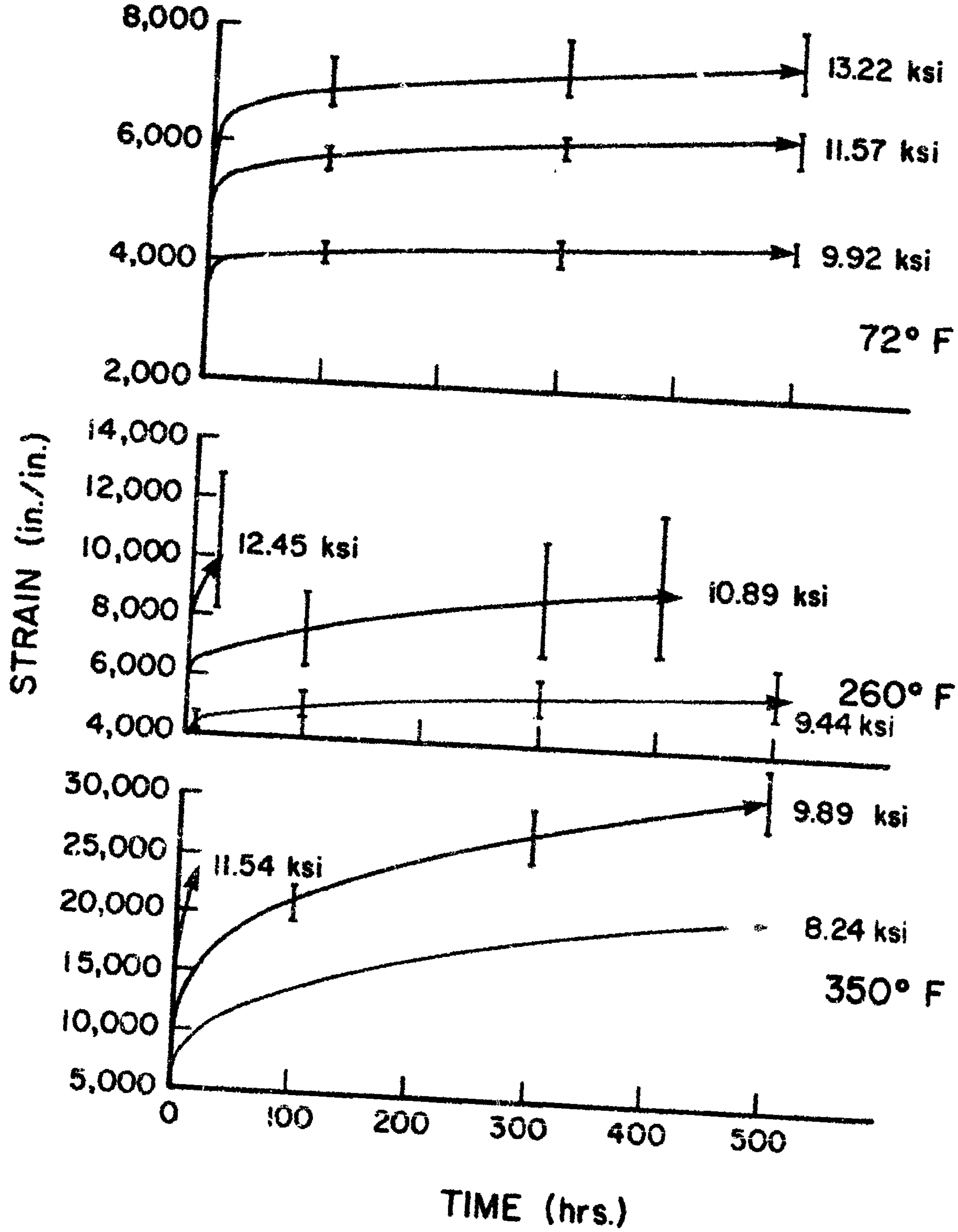


Figure 102. Tensile Creep Behavior of G-160/6535-1 Composite Laminates: ±45° Fiber Orientation.

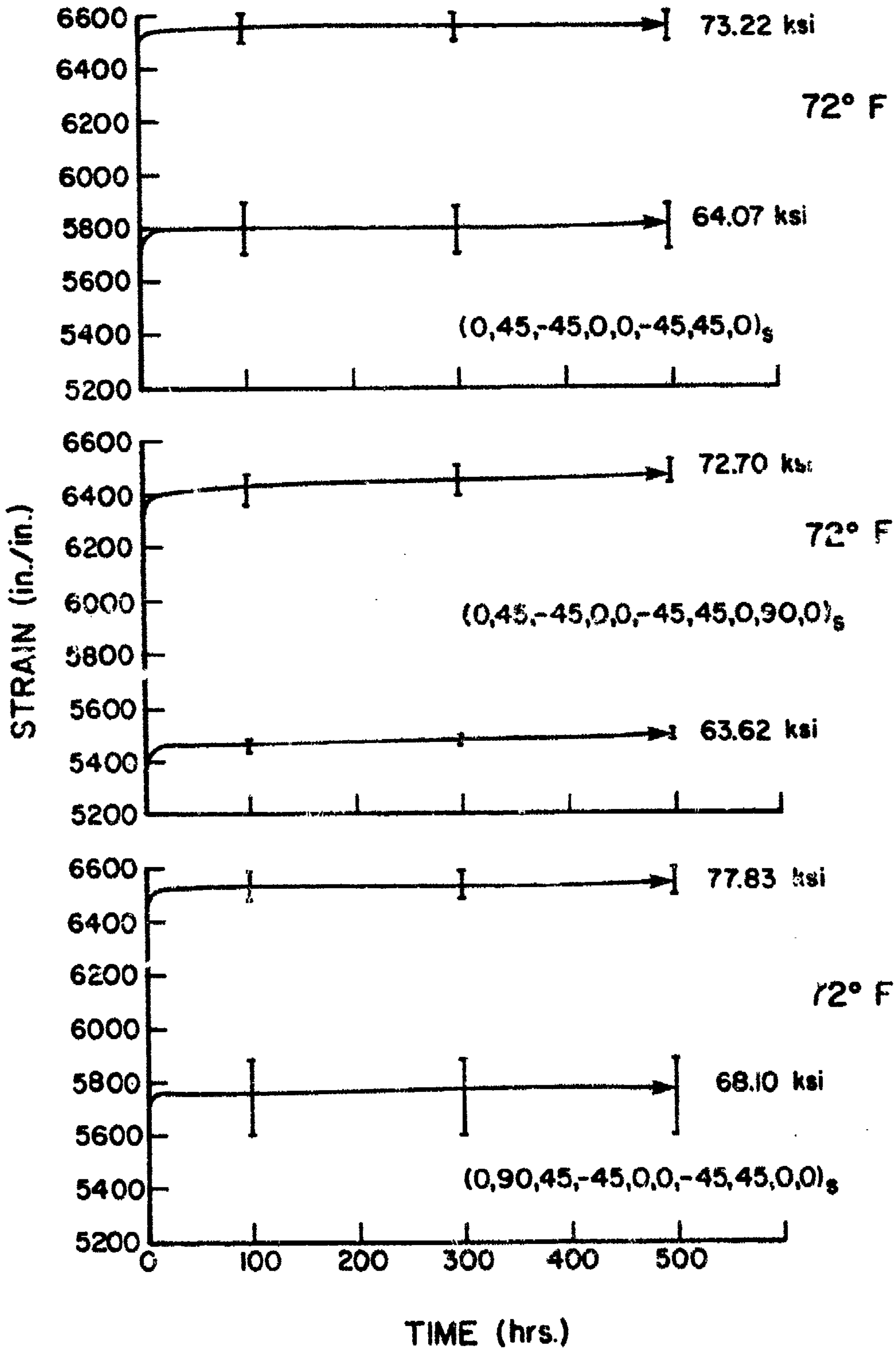


Figure 103. Tensile Creep Behavior of Multidirectional G-160/6535-1 Composite Laminates.

TABLE 85

STRESS-RUPTURE BEHAVIOR OF G-160/6535-1
COMPOSITE LAMINATES

Composite Material Properties	
Material System - G-160/6535-1 Fiber - G-160 Matrix - 6535-1 Maximum Temperature Rating - 350°F(177°C) Resin Content - 26.2% by wt. Fiber Content - 67.8% by vol. Void Content - ≐ 0% by vol. Test Method - Straight-sided tension Reference - ASTM D2290 and D3039	Gr/Ep Prepreg by - AVCO Laminate Sp. Gr. - 1.61 Nominal Ply Thickness - 0.0048 inch(0.12 mm) No. of panels from which specimens were tested in this table - Thickness of each type specimen: ±45 - 8 ply 0/±45/90[2] - 20 ply 0/±45[1] - 16 ply 0/±45/90[3] - 20 ply

STRESS RUPTURE

Temperature	Fiber Orientation	±45	0/±45[1]	0/±45/90[2]	0/±45/90[3]
72°F(22°C)	Stress Level[ksi](MPa)	[13.22](91)	[73.22](504)	[72.70](501)	[77.83](536)
	Time to Failure(hrs)	500+	369+	333+	333+
	No. of Specimens	3	3	3	3
	Residual Strength[ksi](MPa)	[18.17](125)	[108.40](747)	[109.84](757)	[113.85](784)
	No. of Specimens	3	2	2	2
	Stress Level[ksi](MPa)	[11.57](80)	[64.07](441)	[63.62](438)	[68.10](469)
	Time to Failure(hrs)	503+	510+	503+	503+
	No. of Specimens	3	3	3	3
	Residual Strength[ksi](MPa)	[19.30](133)	[103.46](713)	[112.20](773)	[107.24](739)
	No. of Specimens	3	3	3	3
260°F(127°C)	Stress Level[ksi](MPa)	[12.45](86)			
	Time to Failure(hrs)	351+			
	No. of Specimens	3			
	Residual Strength[ksi](MPa)	[14.68](101)			
	No. of Specimens	2			
	Stress Level[ksi](MPa)	[10.89](75)			
	Time to Failure(hrs)	482+			
	No. of Specimens	3			
	Residual Strength[ksi](MPa)	[16.39](113)			
	No. of Specimens	2			
350°F(177°C)	Stress Level[ksi](MPa)	[11.54](80)			
	Time to Failure(hrs)	500+			
	No. of Specimens	3			
	Residual Strength[ksi](MPa)	[16.01](110)			
	No. of Specimens	3			
	Stress Level[ksi](MPa)	[9.89](68)			
	Time to Failure(hrs)	500+			
	No. of Specimens	3			
	Residual Strength[ksi](MPa)	[17.01](117)			
	No. of Specimens	3			

[1] $(0,45,-45,0,0,-45,45,0)_s$ - 16 ply
[2] $(0,45,-45,0,0,-45,45,0,90,0)_s$ - 20 ply
[3] $(0,90,45,-45,0,0,-45,45,0,0)_s$ - 20 ply

TABLE 86

TENSILE-TENSILE FATIGUE PROPERTIES
OF G-160/6535-1 COMPOSITE LAMINATES

Composite Material Properties	
Material System - G-160/6535-1 Prepreg by - AVCO	Gr/Ep
Fiber - G-160 Matrix - 6535-1	Laminate Sp. Gr. - 1.61
Maximum Temperature Rating - 350°F(177°C)	Nominal Ply Thickness - 0.0048 inch (0.12 mm)
Resin Content - 26.2% by wt.	No. of panels from which specimens were tested in this table - 18
Fiber Content - 67.8% by vol.	Thickness of each type specimen:
Void Content - ≐ 0% by vol.	±45 - 8 ply 0/±45/90[2] - 20 ply
Test Method - Straight-sided tension Reference - ASTM D3039	0/±45[1] - 16 ply 0/±45/90[3] - 20 ply

TENSILE FATIGUE, R=0.1

Temperature	Fiber Orientation	±45	0/±45[1]	0/±45/90[2]	0/±45/90[3]
72°F(22°C)	Max. Stress[ksi](MPa)	[14.05](97)	[87.55](603)	[86.39](595)	[77.79](536)
	Lifetime (cycles)	4,603	1,259	962	1,767
	No. of Specimens	5	5	5	5
	Residual Strength[ksi](MPa)	---	---	---	---
	No. of Specimens	0	0	0	0
	Max. Stress[ksi](MPa)	[12.40](85)	[82.69](570)	[81.79](564)	[73.22](504)
	Lifetime (cycles)	69,314	22,478	47,309	99,022
	No. of Specimens	5	5	5	5
	Residual Strength[ksi](MPa)	---	---	---	---
	No. of Specimens	0	0	0	0
	Max. Stress[ksi](MPa)	[10.74](74)	[77.82](536)	[77.25](532)	[68.64](473)
	Lifetime (cycles)	719,082	45,079	154,164	125,270
	No. of Specimens	5	5	5	5
	Residual Strength[ksi](MPa)	---	---	---	---
	No. of Specimens	0	0	0	0
260°F(127°C)	Max. Stress[ksi](MPa)	[13.23](91)			
	Lifetime (cycles)	3,438			
	No. of Specimens	5			
	Residual Strength[ksi](MPa)	---			
	No. of Specimens	0			
	Max. Stress[ksi](MPa)	[10.89](75)			
	Lifetime (cycles)	138,999			
	No. of Specimens	5			
	Residual Strength[ksi](MPa)	---			
	No. of Specimens	0			
	Max. Stress[ksi](MPa)	[8.56](59)			
	Lifetime (cycles)	3,640,227			
	No. of Specimens	5			
	Residual Strength[ksi](MPa)	---			
	No. of Specimens	0			

[1] $(0,45,-45,0,0,-45,45,0)_s$ - 16 ply
[2] $(0,45,-45,0,0,-45,45,0,90,0)_s$ - 20 ply
[3] $(0,90,45,-45,0,0,-45,45,0,0)_s$ - 20 ply

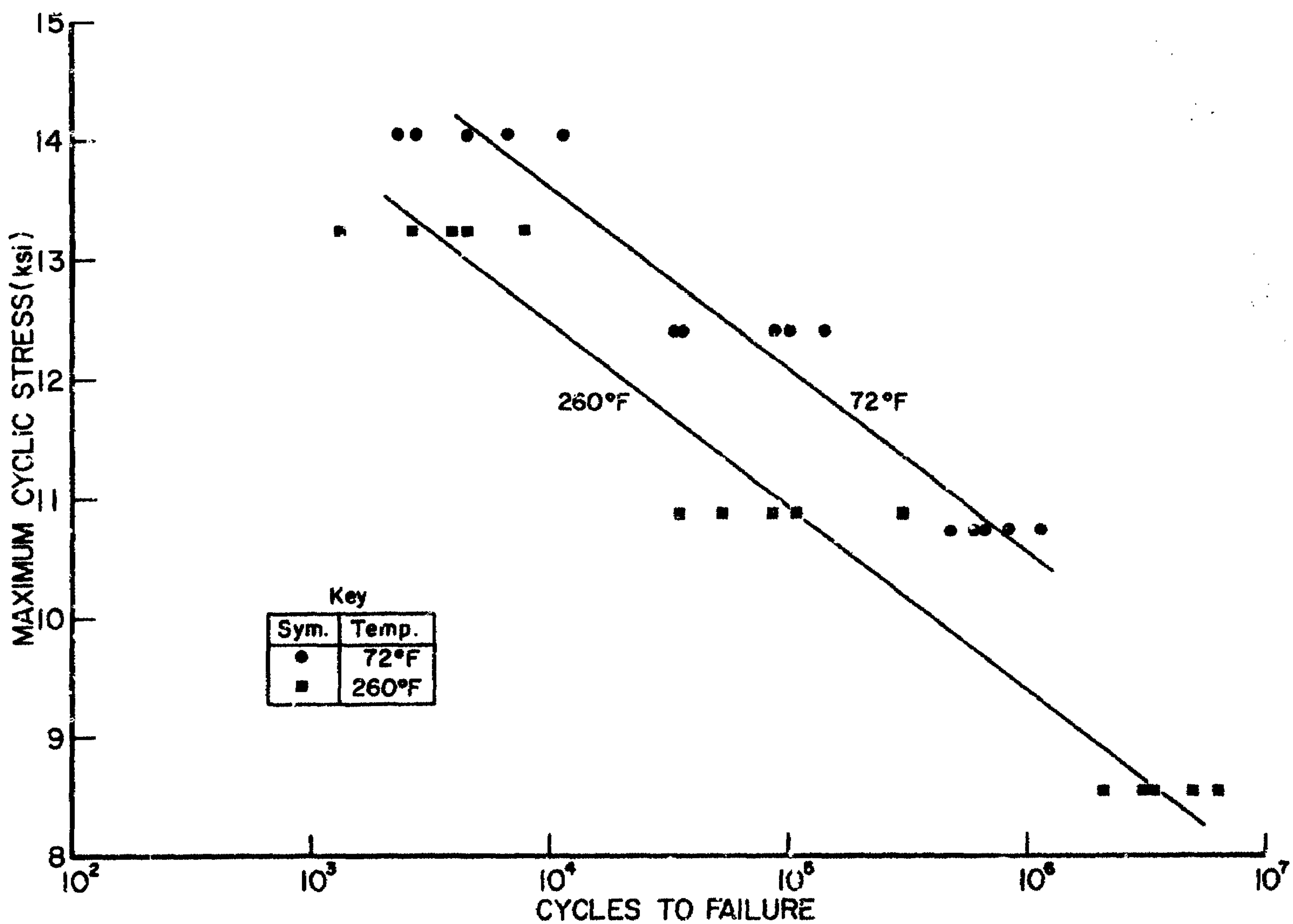


Figure 104. Tensile-Tensile Fatigue Behavior of Bidirectional G-160/6535-1 Composite Laminates: ±45° Fiber Orientation.

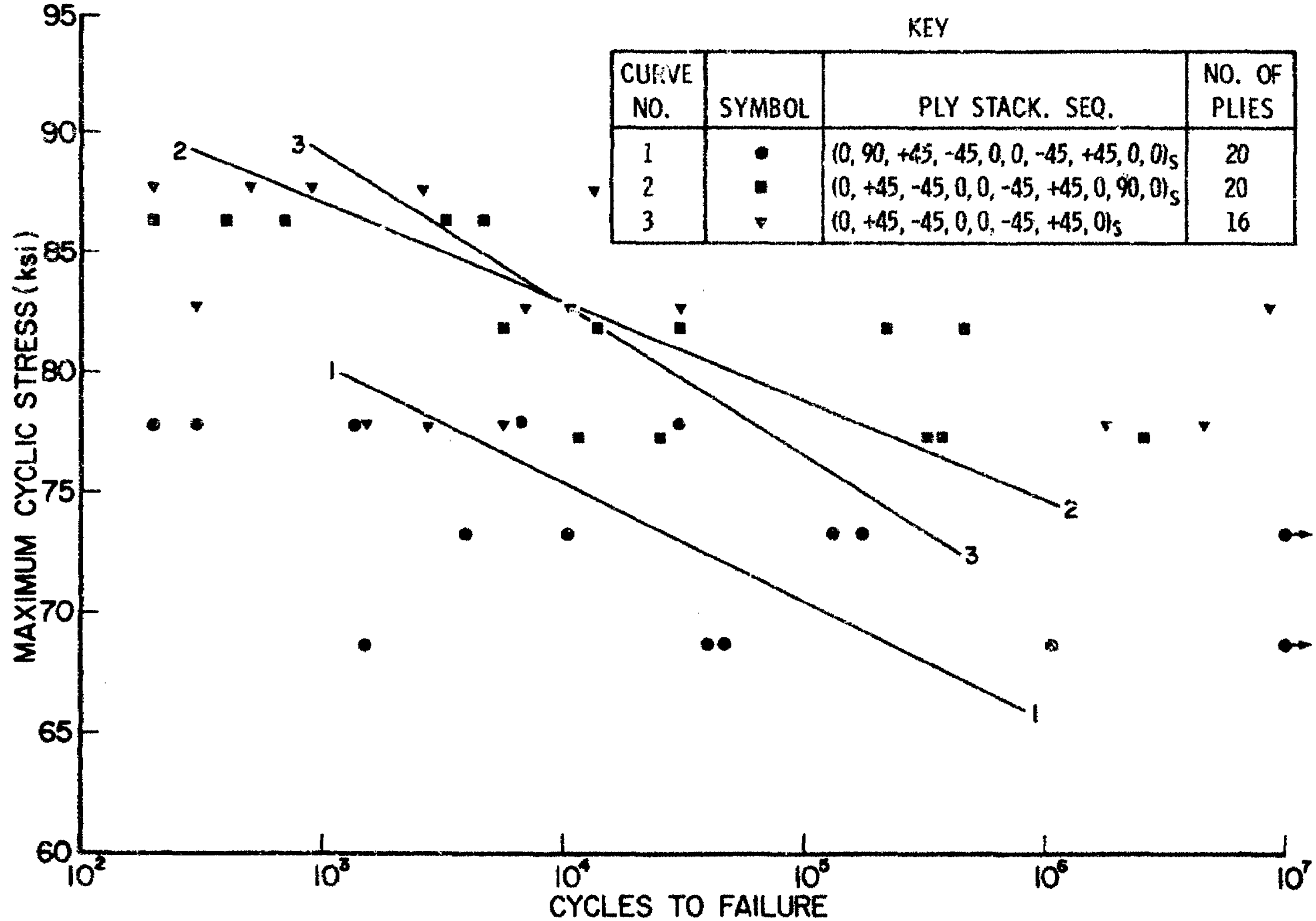


Figure 105. Tensile-Tensile Fatigue Behavior of Multidirectional G-160/6535-1 Composite Laminates.

TABLE 87

THERMOPHYSICAL PROPERTIES OF G-160/6535-1 COMPOSITE LAMINATES

Composite Material Properties					
Material System - G-160/6535-1 Fiber - G-160 Matrix - 6535-1 Maximum Temperature Rating - 350°F(177°C) Resin Content - 25.5% by wt. Fiber Content - 68.5% by vol. Void Content - ≐ 0% by vol. Thickness of each type specimen: Therm. Exp. - 40 ply Therm. Cond. -40 ply	Prepreg by - AVCO Laminate Sp. Gr. - 1.61 Average Ply Thickness - 0.0048 inch(0.12 mm) No. of panels from which specimens were tested in this table - 3 Spec. Ht. - 1 ply Glass Trans. -8 ply				Gr/Epoxy
THERMOPHYSICAL PROPERTIES: 0°					
	-67°F(-55°C)	72°F(22°C)	260°F(127°C)	350°F(177°C)	Test Method
Thermal Expansion[1]					
α_x[μin/in-°F](μcm/cm-°C)	[0.04](0.08)	[-0.21](-0.37)	[-0.21](-0.38)	[-0.10](-0.20)	TMA[2]
α_y[μin/in-°F](μcm/cm-°C)	[12.5](22.5)	[13.8](24.8)	[16.7](30.0)	[18.0](32.4)	
No. of Specimens per direction	3	3	3	3	
Specific Heat C_p[btu/lb.-°F](J/kg-°C)	[0.154](644)	[0.202](845)	[0.281](1175)	[0.333](1393)	DSC[3]
No. of Specimens	3	3	3	3	
Thermal Conductivity[1] k_z[btu-ft/ft^2-hr-°F] (W/m-°C)	[0.23] (0.40)	[0.38] (0.66)	[0.57] (0.99)	[0.66] (1.14)	Comparative
No. of Specimens	3	3	3	3	
Glass Transition Temp.					DMA[4]
Dry [°F](°C)	[507] (264)				
Wet [°F](°C)	[471] (244)				
THERMOPHYSICAL PROPERTIES: ±45°					
Thermal Expansion[1]					
α_x[μin/in-°F](μcm/cm-°C)	[1.63](2.93)	[1.37](2.46)	[1.24](2.24)	[1.41](2.54)	TMA[2]
No. of Specimens per direction	3	3	3	3	
Thermal Conductivity[1] k_z[btu-ft/ft^2-hr-°F] (W/m-°C)	[0.37] (0.64)	[0.43] (0.74)	[0.51] (0.88)	[0.55] (0.95)	Comparative
No. of Specimens	3	3	3	3	

NOTES: 1. On the unidirectionally reinforced specimens, the x-direction is along the fiber axis, the y-direction is across the fiber axis, and the z-direction is through the thickness (identical to the y-direction). On ±45° bidirectionally reinforced specimens, the x and y directions are identical and oriented at 45° to either fiber direction, while the z-direction is through the thickness.
2. Thermo-mechanical Analysis.
3. Differential Scanning Calorimetry.
4. Dynamic Mechanical Analysis.

4.7 COMPARATIVE ENVIRONMENTAL BEHAVIOR

One of the points of particular interest relative to the data generated in this program is the comparative susceptibility of the different composite materials to degradation during, or as the result of, elevated temperature, high humidity aging. Figures 106 through 108 illustrate the effect of both test temperature and moisture absorption upon the strength retention of these composite materials. The notations "saturated" and "50% saturated", recall, refer to the specimen condition just prior to testing. As discussed in Section 3.4, the specimens tested at elevated temperature undoubtedly dry out to some extent during the testing process, with the smaller specimens (shear and compression) drying out more rapidly than the larger tensile specimens.

Additionally, use of the description, "50% saturated", refers to the partial saturation condition. While the aging periods were selected so as to effect about 50% as much moisture absorption as is present at equilibrium, the actual levels of partial saturation range from 45-67% of the fully saturated levels. Further, it must be recognized that while a specimen permitted to reach an equilibrium saturation condition may have a relatively uniform moisture concentration throughout its thickness, one only "50% saturated" will have most of that moisture concentrated near the surfaces.

Several features in Figures 106-108 stand out. First, the strength levels for the HyE 2034D system (employing the 75 Msi [517 GPa], pitch-based graphite fiber) are lower for every type of test and for every temperature and moisture level than any of the other materials. This is probably due to a lower level of interfacial bonding between this particular reinforcing fiber and the 934 epoxy matrix. Relative to the strength levels in the dry material, the HyE 2034D system loses the least strength due to absorbed moisture of any of the other five materials. This, however, is probably the result

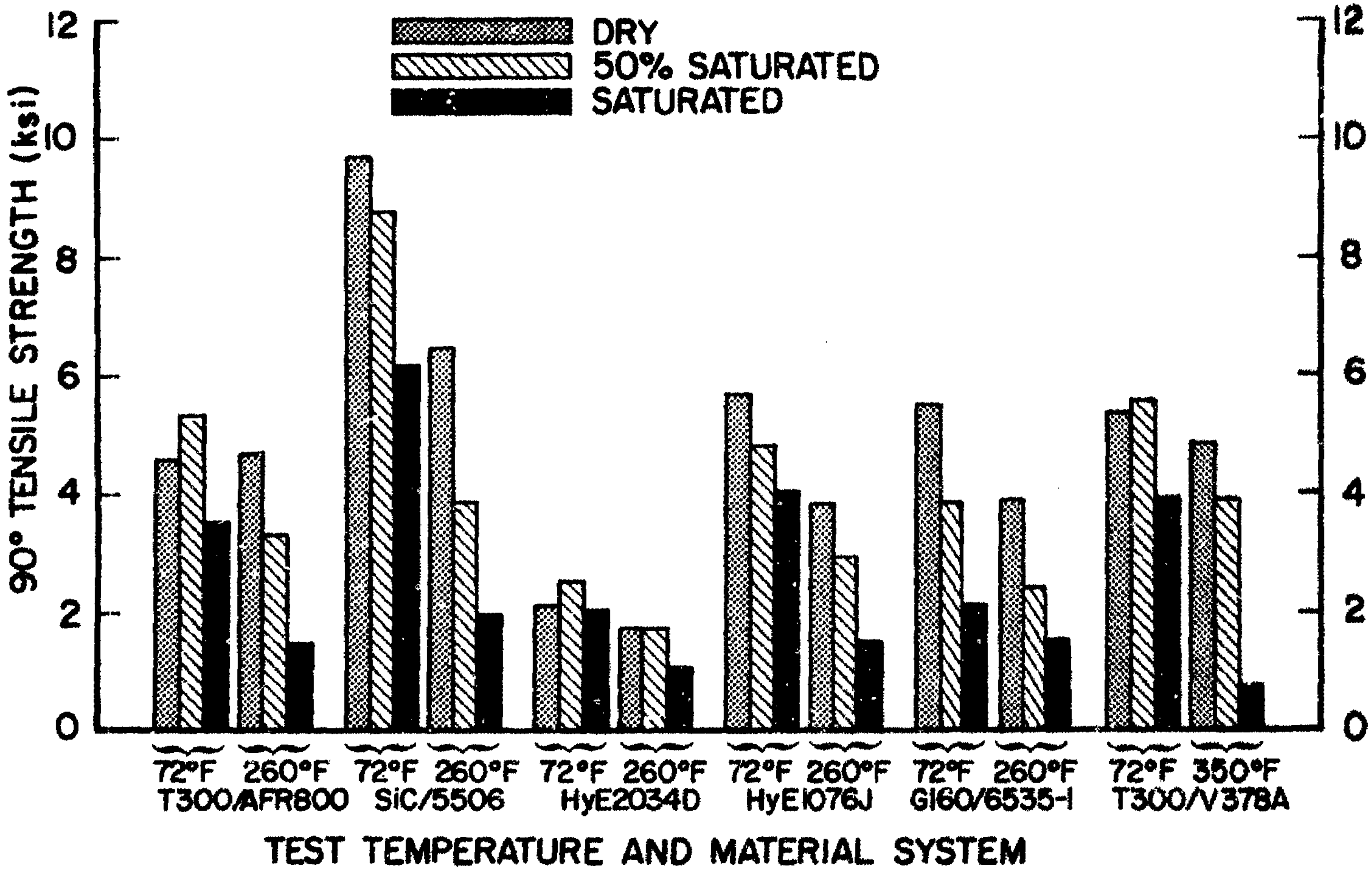


Figure 106. Comparative Transverse Tensile Strength Retention After Aging at 160°F(71°C) and 100% Relative Humidity.

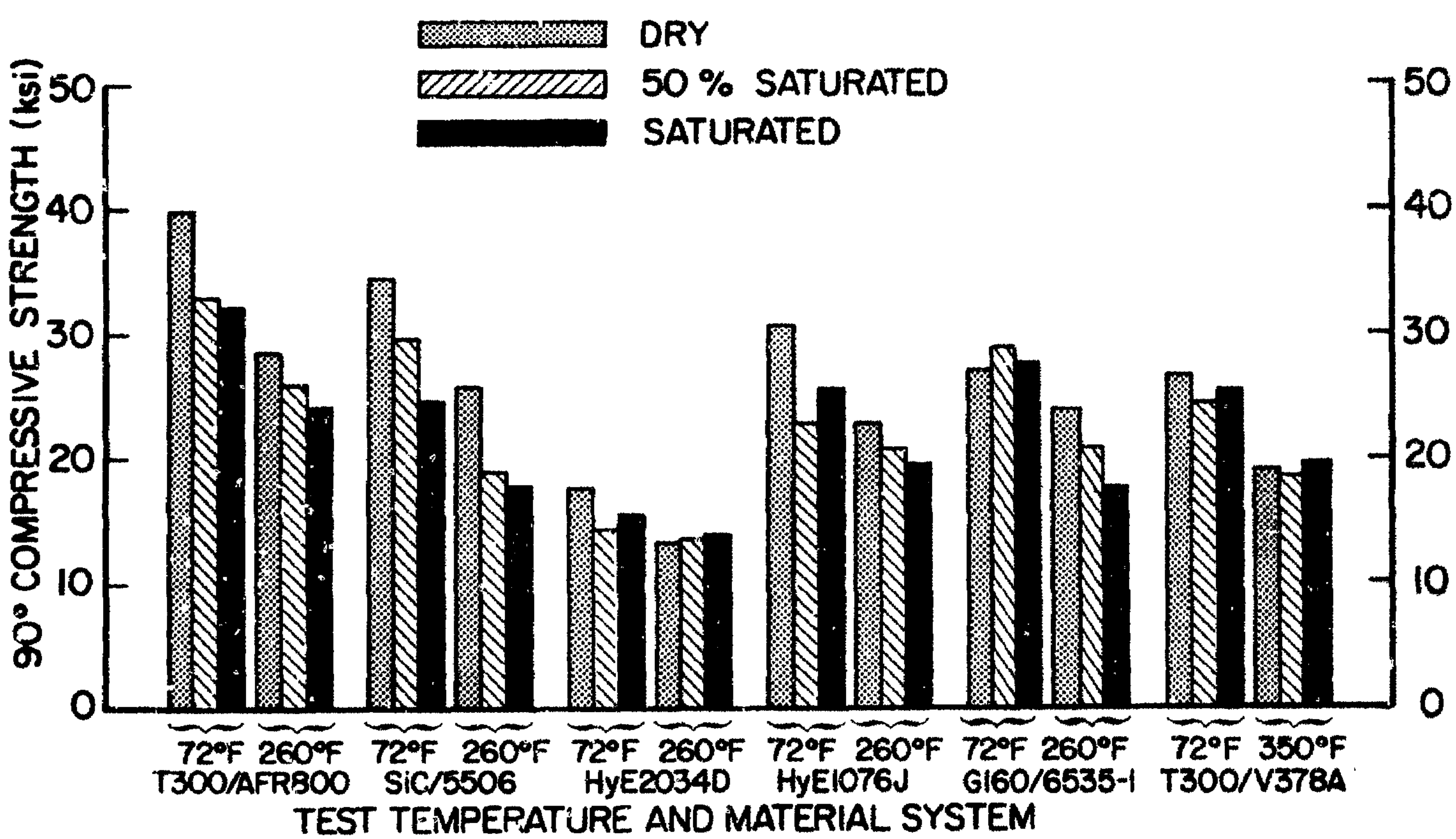


Figure 107. Comparative Transverse Compressive Strength Retention After Aging at 160°F (71°C) and 100% Relative Humidity.

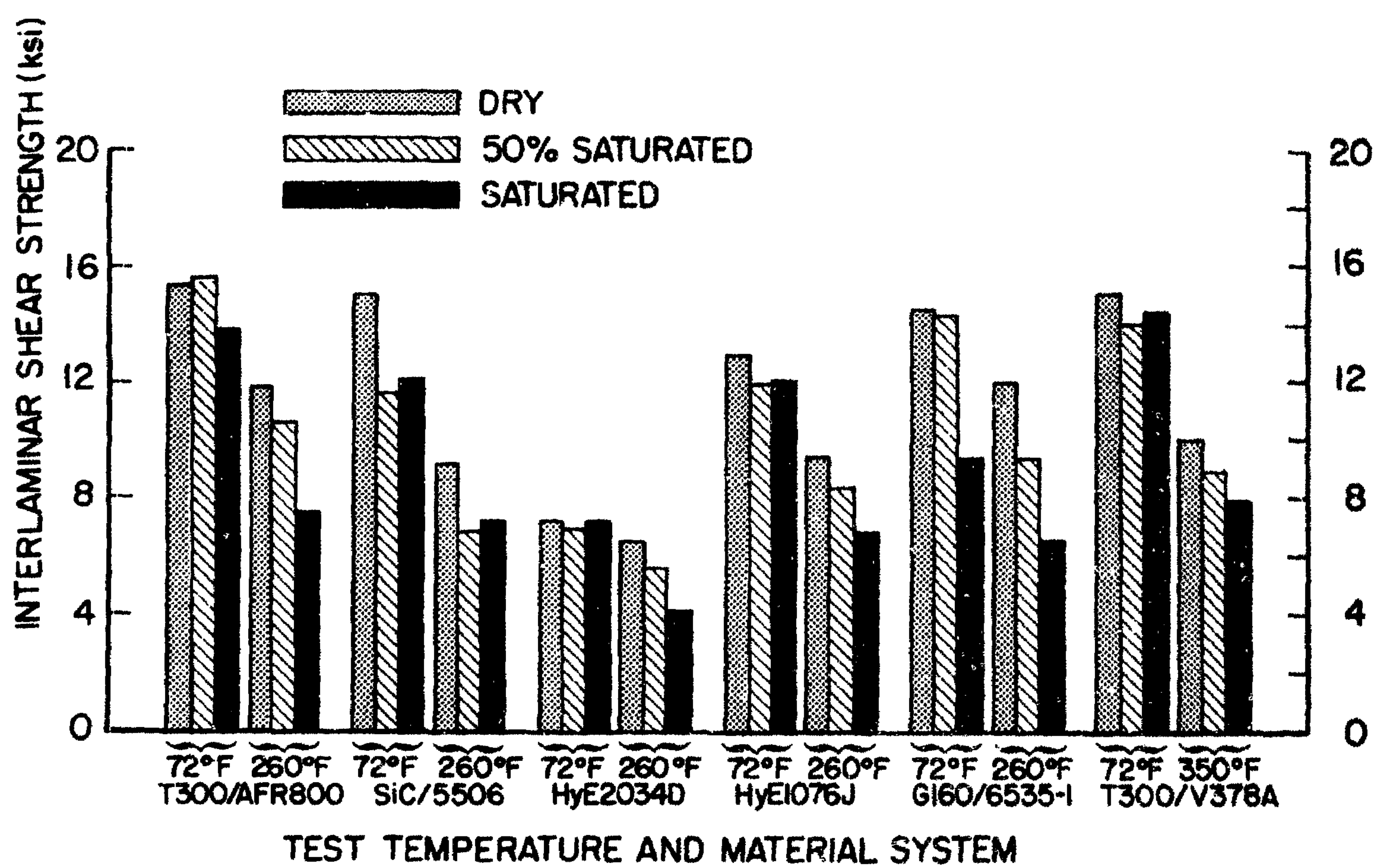


Figure 108. Comparative Interlaminar Shear Strength Retention After Aging at 160°F (71°C) and 100% Relative Humidity.

of the original below average interfacial bond strengths since the wet strength levels of the other epoxy-matrix systems are comparable to the dry strength level of the HyE 2034D.

Second, while the SiC/5506 system loses the most strength, relative to the dry state, of any of the materials tested, its absolute strength levels in 90° tension are clearly the highest and its absolute strength levels in 90° compression and interlaminar shear are comparable to the other materials.

In those instances in which a more saturated condition resulted in a higher strength than a less saturated condition, the difference is small enough to be attributable to experimental scatter.

While the fact that the T300/V378A system (polyimide) was tested at 350°F (177°C) rather than 260°F (127°C) makes it less than straightforward to compare it directly with the other five systems (all epoxy), it would appear, with the possible exception of the 350°F (177°C) saturated condition, that this material suffers less degradation due to moisture absorption than any of the other materials tested.

Elevated temperature, high humidity agings similar to those conducted during this program were previously carried out on two other polyimide systems, AS/4397 by Hercules, and T300/F178 by Hexcel, and reported in AFML-TR-77-151.[14] Comparison of the 90° tension and interlaminar shear data (both dry and humidity aged) of these two materials with that for the T300/V378A system reveals that the latter material exhibits generally equivalent or superior strength levels to either of the two systems tested earlier. This in spite of the fact that the latter material had a void content of about 0.8% while the two earlier materials were void free.

SECTION 5
CONCLUSIONS

Each of the conclusions listed in this section was arrived at through inspection of the data in Section 4 and represent generalizations of overall composite behavior. Exceptions to each of these generalized conclusions can be found if the data are scrutinized in sufficient detail. In most cases, these exceptions are at least mentioned and discussed.

1. The static strengths (tensile, compressive, flexural, inplane, and interlaminar shear) of each material evaluated in this program decreased with increasing test temperature. In those cases where this was not true, the exception usually proved to be either in a tensile specimen dominated by 0° plies, or at -67°F (-55°C). The latter situation most probably is due to increased sensitivity to brittle failure at the lower temperature.

2. In those cases where the elastic modulus is primarily fiber dependent, the test temperature had relatively little effect on the modulus (0° tension, 0/$\pm$45/90 tension, 0° compression, 0° flexure). In those cases where the composite modulus is primarily matrix dependent, however, the modulus for each material decreased with increasing temperature just as the strengths did.

3. The ultimate elongations of the fiber dependent specimens behaved in roughly the same fashion as the strength, and with the same exceptions. The ultimate elongations of the matrix dependent specimens (90° and $\pm$45° tension and 90° compression) increased with increasing temperature for any specific stress. Since the ultimate stress for these specimens, however, was simultaneously decreasing, the actual ultimate elongations for these type specimens exhibited some increases and some decreases with increasing test temperature.

4. On those systems in which holes were drilled in the center of the multidirectional tensile specimens, the static tensile strength was 76-80% of what it would have been had it followed the reduction in cross-sectional area directly. This reduction is probably due to the creation of a stress concentration around the hole (diameter = 0.1935 x width of specimen).

5. On the last material tested, the presence, absence, and location of a 90° ply in the layup stack was varied because of its influence on normal edge stresses. The static tensile results indicated that the layup with a low level of normal edge stress produces a slightly higher tensile strength, while the layups which produce large tensile and large compressive edge stresses produce equivalent, and slightly lower tensile strengths. In fatigue, the layup which produces large tensile edge stresses and the stress-free layup exhibit longer lifetimes, for equivalent cyclic stress levels, than the layup which produced large compressive edge stresses. The former two layups (stress-free and tensile edge stress) exhibit comparable fatigue behavior. The difference in slope may be insignificant considering the limited amount of available data and the degree of scatter.

6. The thermal conductivity and specific heat increased with increasing temperature for all six systems.

7. The coefficient of thermal expansion (CTE) seemed relatively independent of temperature for the four systems incorporating high strength graphite fiber. On the HyE 2034D system, however, incorporating a high

modulus graphite fiber, the CTE decreased with increasing temperature while the system incorporating silicon carbide fiber exhibited an increasing CTE with temperature.

8. On all of the graphite reinforced systems, the layups incorporating 0° plies exhibited considerable scatter in fatigue lifetimes. The silicon carbide reinforced system, on the other hand, exhibited much less scatter in fatigue lifetimes on layups incorporating 0° plies. Along with the greater scatter in the graphite systems, however, these systems exhibited considerably longer fatigue lifetimes than the silicon carbide system at comparable cyclic stress levels.

   For the ±45° orientations, there was relatively little scatter on any of the materials. For this orientation, the high strength graphite systems again exhibit considerably longer fatigue lifetimes than the silicon carbide system for comparable cyclic stress levels. The high modulus graphite system outperforms the silicone carbide system in fatigue for the ±45° orientation if the cyclic stress levels are converted to percent of static tensile strength.

9. The relatively large plastic strains undergone by the ±45° orientation led, in some cases, to substantial internal energy dissipation and self-heating in fatigue tests. For the materials tested here, this self heating caused typical temperature increases in ±45° orientations of 8-20°F (4-11°C) for cyclic stress levels in the range of 60-85% of the static ultimate. There were some specimens of course that exhibited practically no self heating while others exhibited temperature rises of up to 40°F (22°C).

10. Probably the most unusual thing observed in the creep testing was the tendency of some of the multidirectional layups (0/$\pm$45/90), particularly at elevated temperature and with the high modulus graphite fiber, to exhibit contraction rather than extension. This was not observed with the silicon carbide system. It may be attributable to the gradual relief of residual internal stresses resulting from laminate fabrication.

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APPENDIX A

COMPUTATION OF NORMAL EDGE STRESSES

It is well known that a flat composite laminate which is subjected to a basically in-plane system of loads can develop normal interlaminar stresses near free edges that are sufficient to cause delamination. This phenomenon occurs because a composite laminate is not a two-dimensional structure at all, but is a complex, non-homogeneous, three-dimensional system. In a macromechanical sense a composite laminate distributes loads much like a plate composed of a single homogeneous material. In the center of a laminate structure, at points distant from boundaries and points of load applications, the macromechanics theory of composites is sufficient to represent the state of stress accurately. However, near boundaries such as the free edges of a tension specimen, the state of stress is three-dimensional and depends on the laminate stacking sequence. In particular, interlaminar normal stresses at a free edge can be so affected by stacking sequence that changes in sign may occur simply by rearranging the layers.

This Appendix presents a brief discussion of the procedure used for analytically determining the interlaminar normal edge stresses in a composite tensile specimen. The method involves the following two steps:

(1) Computation of the nominal stresses in each layer using macromechanics composite theory, as presented in References 15 and 16, and;

(2) Estimation of the normal stresses between individual lamina, according to the method presented in References 17-19.

These analysis steps are discussed individually below in Sections A.1 and A.2. Section A.3 contains interlayer normal stresses computed for example composite tensile layups of various materials.

A.1 LAYER STRESSES

The nominal layer stresses in a composite laminate are computed by means of standard macromechanics theory. For completeness, the relevant equations are presented below for a general laminated composite; the special case of narrow test specimens with free edges will be considered in Section A.2

A.1.1 Stress Resultants

It is presumed that a stress analysis has been performed on a composite plate (we will specialize to the case of a tension specimen in Section A.2) referred to a two-dimensional Cartesian coordinate system x,y; that is, at every point x,y, the in-plane stress resultants N_x, N_y, N_{xy} and the moment stress resultants M_x, M_y, M_{xy} have been determined (by plate theory, from a finite element analysis, by experimentation, etc.). These stress resultants arise from a system of mechanical and thermal loads, and they act at a reference plane (usually the middle surface) with the positive conventions shown in Figure A-1.

A.1.2 Lamina Properties

The x,y coordinate system of Figure A-1 is referred to as the structural axes. An individual lamina is referred to a 1,2 set of material axes as shown in Figure A-2. The lamina fibers are oriented along the material 1-axis which is measured relative to the structural x-axis by the angle θ. The in-plane material properties of the lamina are referred to by:

Moduli of elasticity: E_1, E_2

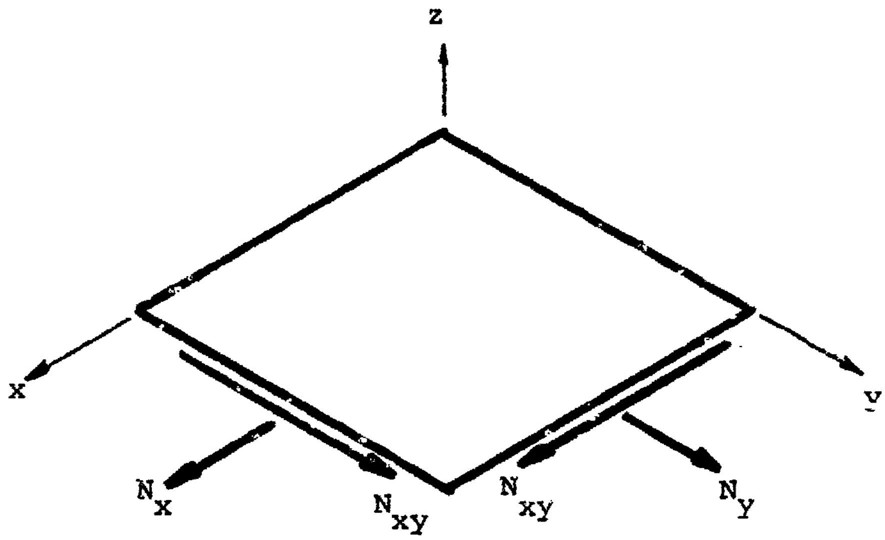
Poisson's Ratio : ν_{12}, $\nu_{21} = \frac{E_2}{E_1} \nu_{12}$

Shear Modulus : G_{12}

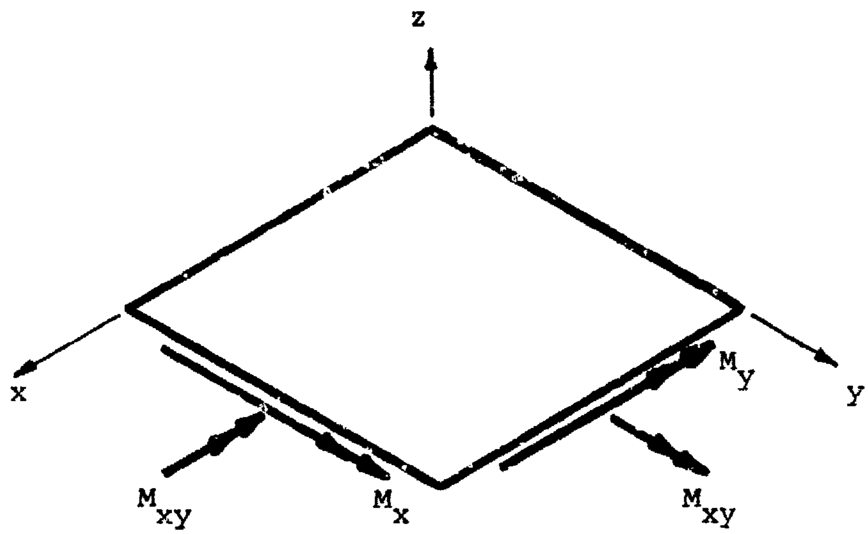
Thermal Coefficients: α_1, α_2

The stress-strain relationship for the lamina is written as

$$\begin{Bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_{12} \end{Bmatrix} = [Q] \begin{Bmatrix} \varepsilon_1 - \alpha_1 \Delta T \\ \varepsilon_2 - \alpha_2 \Delta T \\ \varepsilon_{12} \end{Bmatrix} \tag{A.1}$$



Membrane Stress Resultants



Bending Stress Resultants

Figure A-1. Stress Resultants at the Mid-Surface of a Composite Laminate.

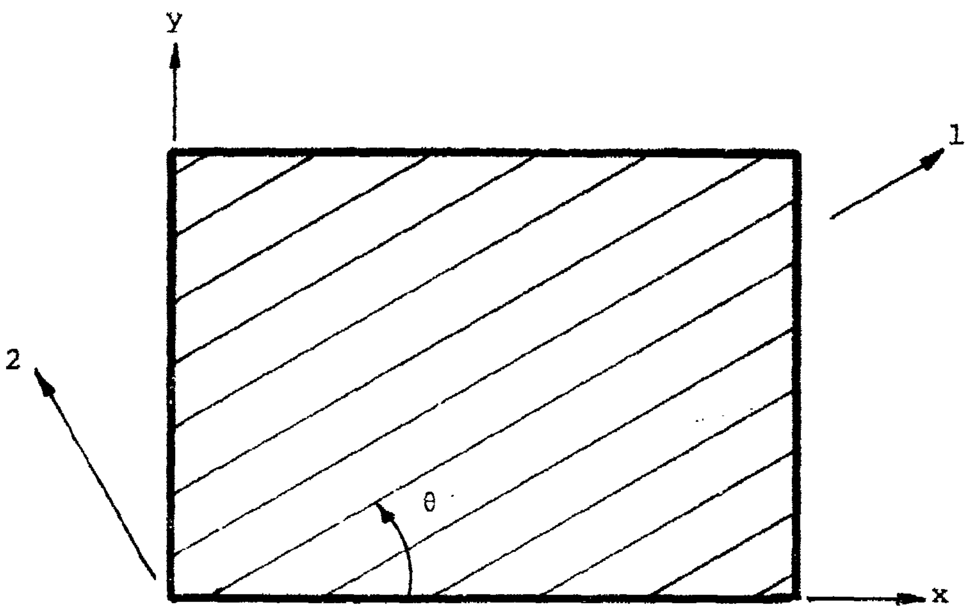


Figure A-2. Typical Lamina.

where ΔT is a change in temperature, and

$$[Q] = \begin{bmatrix} Q_{11} & Q_{12} & 0 \\ Q_{21} & Q_{22} & 0 \\ 0 & 0 & Q_{66} \end{bmatrix} \tag{A.2}$$

where,

$$Q_{11} = \frac{E_1}{1 - \nu_{12}\,\nu_{21}}$$

$$Q_{22} = \frac{E_2}{1 - \nu_{12}\,\nu_{21}}$$

$$Q_{12} = Q_{21} = \frac{\nu_{12}\,E_2}{1 - \nu_{12}\,\nu_{21}} = \frac{\nu_{21}\,E_1}{1 - \nu_{12}\,\nu_{21}} \tag{A.3}$$

$$Q_{66} = G_{12}$$

If the lamina material properties are referred to the structural axes rather than the material axes, the following transformations are performed:

$$[\bar{Q}] = [T]^{-1}[Q][T]^{-T} \tag{A.4}$$

$$\begin{Bmatrix} \alpha_x \\ \alpha_y \\ \alpha_{xy} \end{Bmatrix} = [T]^T \begin{Bmatrix} \alpha_1 \\ \alpha_2 \\ 0 \end{Bmatrix} \tag{A.5}$$

where the transformation matrix is given by

$$[T] = \begin{bmatrix} \cos^2\theta & \sin^2\theta & 2\sin\theta\cos\theta \\ \sin^2\theta & \cos^2\theta & -2\sin\theta\cos\theta \\ -\sin\theta\cos\theta & \sin\theta\cos\theta & \cos^2\theta\sin^2\theta \end{bmatrix} \tag{A.6}$$

and its inverse is,

$$[T]^{-1} = \begin{bmatrix} \cos^2\theta & \sin^2\theta & -2\sin\theta\cos\theta \\ \sin^2\theta & \cos^2\theta & 2\sin\theta\cos\theta \\ \sin\theta\cos\theta & -\sin\theta\cos\theta & \cos^2\theta-\sin^2\theta \end{bmatrix} \qquad \text{(A.7)}$$

A.1.3 Laminate Properties

Consider a laminate formed by stacking individual laminae as shown in Figure A-3. A typical lamina is referred to by "k". For example, the thickness of layer k is h_k and the transformed material property matrix is $[\bar{Q}]_k$.

The stress-strain relationship for a laminate in terms of the reference surface stress resultants (N_x, N_y, N_{xy}, M_x, M_y, M_{xy}) computed as indicated in Section A.1, and the reference surface strains (ε_{xo}, ε_{yo}, γ_{xyo}) and curvatures (κ_x, κ_y, κ_{xy}) is given by

$$\left[\begin{array}{ccc|ccc} A_{11} & A_{12} & A_{16} & B_{11} & B_{12} & B_{66} \\ A_{12} & A_{22} & A_{26} & B_{12} & B_{22} & B_{26} \\ A_{16} & A_{26} & A_{66} & B_{16} & B_{26} & B_{66} \\ \hline B_{11} & B_{12} & B_{16} & D_{11} & D_{12} & D_{16} \\ B_{12} & B_{22} & B_{26} & D_{12} & D_{22} & D_{26} \\ B_{16} & B_{26} & B_{66} & D_{16} & D_{26} & D_{66} \end{array}\right] \left\{\begin{array}{c} \varepsilon_{xo} \\ \varepsilon_{yo} \\ \gamma_{xyo} \\ \hline \kappa_x \\ \kappa_y \\ \kappa_{xy} \end{array}\right\} = \left\{\begin{array}{c} N_x \\ N_y \\ N_{xy} \\ \hline M_x \\ M_y \\ M_{xy} \end{array}\right\} + \left\{\begin{array}{c} N_{xt} \\ N_{yt} \\ N_{xyt} \\ \hline M_{xt} \\ M_{yt} \\ M_{xyt} \end{array}\right\} \Delta T \qquad \text{(A.8)}$$

where the composite material properties are determined by

$$A_{ij} = \sum_{k=1}^{N} (\bar{Q}_{ij})_k \, (z_k - z_{k-1})$$

$$B_{ij} = \frac{1}{2} \sum_{k=1}^{N} (\bar{Q}_{ij})_k \, (z_k^2 - z_{k-1}^2) \qquad \text{(A.9)}$$

$$D_{ij} = \frac{1}{3} \sum_{k=1}^{N} (\bar{Q}_{ij})_k \, (z_k^3 - z_{k-1}^3)$$

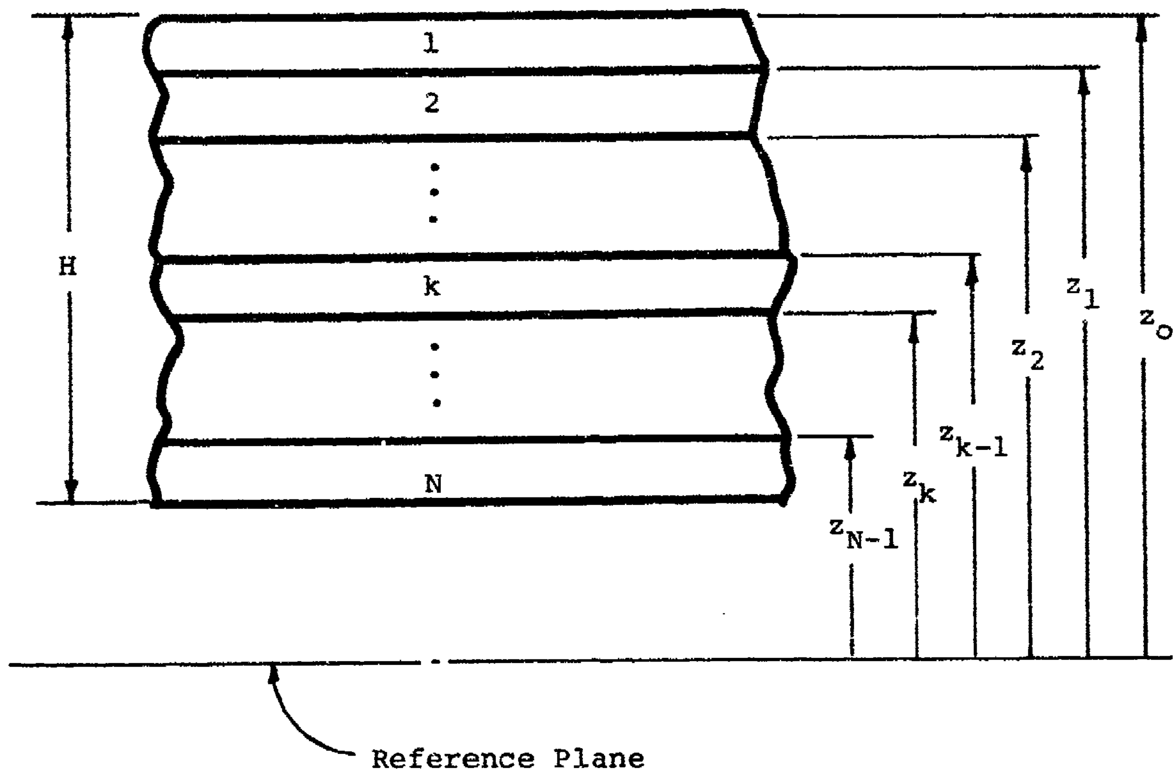


Figure A-3. Composite Laminate.

and the stress resultants due to thermal change are,

$$\begin{Bmatrix} N_{xt} \\ N_{yt} \\ N_{xyt} \end{Bmatrix} = \Delta T \sum_{k=1}^{N} \begin{bmatrix} \bar{Q}_{11} & \bar{Q}_{12} & \bar{Q}_{16} \\ \bar{Q}_{12} & \bar{Q}_{22} & \bar{Q}_{26} \\ \bar{Q}_{16} & \bar{Q}_{26} & \bar{Q}_{66} \end{bmatrix}_k \begin{Bmatrix} \alpha_x \\ \alpha_y \\ \alpha_{xy} \end{Bmatrix}_k (z_k - z_{k-1})$$

(A.10)

$$\begin{Bmatrix} M_{xt} \\ M_{yt} \\ M_{xyt} \end{Bmatrix} = \frac{\Delta T}{2} \sum_{k=1}^{N} \begin{bmatrix} \bar{Q}_{11} & \bar{Q}_{12} & \bar{Q}_{16} \\ \bar{Q}_{12} & \bar{Q}_{22} & \bar{Q}_{26} \\ \bar{Q}_{16} & \bar{Q}_{26} & \bar{Q}_{66} \end{bmatrix}_k \begin{Bmatrix} \alpha_x \\ \alpha_y \\ \alpha_{xy} \end{Bmatrix} (z_k^2 - z_{k-1}^2)$$

A.1.4 Strain and Stress in the Laminae

The strains (ε_{xo}, ε_{yo}, γ_{xyo}) and the curvatures (κ_x, κ_y, κ_{xy}) of the laminate reference surface are determined by solving the Equation A.8. The in-plane strains in the laminate at a distance Z from the reference plane are then written as

$$\begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} = \begin{Bmatrix} \varepsilon_{xo} \\ \varepsilon_{yo} \\ \gamma_{xyo} \end{Bmatrix} + Z \begin{Bmatrix} \kappa_x \\ \kappa_y \\ \kappa_{xy} \end{Bmatrix} \qquad \text{(A.11)}$$

The stresses at position z are

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_{xy} \end{Bmatrix} = \begin{bmatrix} \bar{Q}_{11} & \bar{Q}_{12} & \bar{Q}_{16} \\ \bar{Q}_{12} & \bar{Q}_{22} & \bar{Q}_{26} \\ \bar{Q}_{16} & \bar{Q}_{26} & \bar{Q}_{66} \end{bmatrix} \left\{ \begin{Bmatrix} \varepsilon_{xo} \\ \varepsilon_{yo} \\ \gamma_{xy} \end{Bmatrix} - \begin{Bmatrix} \alpha_x \\ \alpha_y \\ \alpha_{xy} \end{Bmatrix} \Delta T + Z \begin{Bmatrix} \kappa_x \\ \kappa_y \\ \kappa_{xy} \end{Bmatrix} \right\} \qquad \text{(A.12)}$$

When Z lies within layer k, then the subscript k is presumed to be attached to the material properties in Equation A.12.

A.2 NORMAL INTERLAMINAR EDGE STRESSES

Consider a laminated composite tension specimen as shown in Figure A-4. Depending on the stacking sequence of the laminae which compose the laminate, the free edge indicated in the figure can undergo delamination failure before the laminate as a whole fails. The occurrence of this disturbing phenomenon led to the development of the theory presented in References 16-19 and summarized below.

The stress resultants in the specimen due to the applied load P in the x-direction are clearly

$$N_x = \frac{P}{2b}$$

$$N_y = N_{xy} = M_x = M_y = M_{xy} = 0 \tag{A.13}$$

Then the strains and stresses in the various lamina are computed by solving Equation A.8, and evaluating Equations A.11 and A.12 for appropriate values of Z. In this case the lamina stresses are constant through the thickness of each layer.

Figure A-5 shows a section cut from the laminate; the section geometry is characterized by one unit in the x-direction, a symmetric half in the y-direction, and full thickness in the z direction. The forces acting on the laminate in the y-direction are also shown on the figure. Since the free edge is stress free, the forces acting at the y=0 must balance through the layers. Now consider layer number 1 which is isolated in Figure A-6. Clearly, since the edge y=b is stress free, there must be some area near the free edge which must develop an interlaminar shear force F_1 and moment M_1 to balance the force $\sigma_{y1}\, h_1$ acting at y=0. This line of reasoning can be extended to conclude that all layers must develop interlaminar edge forces and moments as shown in Figure A-7.

If the typical layer k is required to be in equilibrium with respect to force-sums and moment sums, the following equations result:

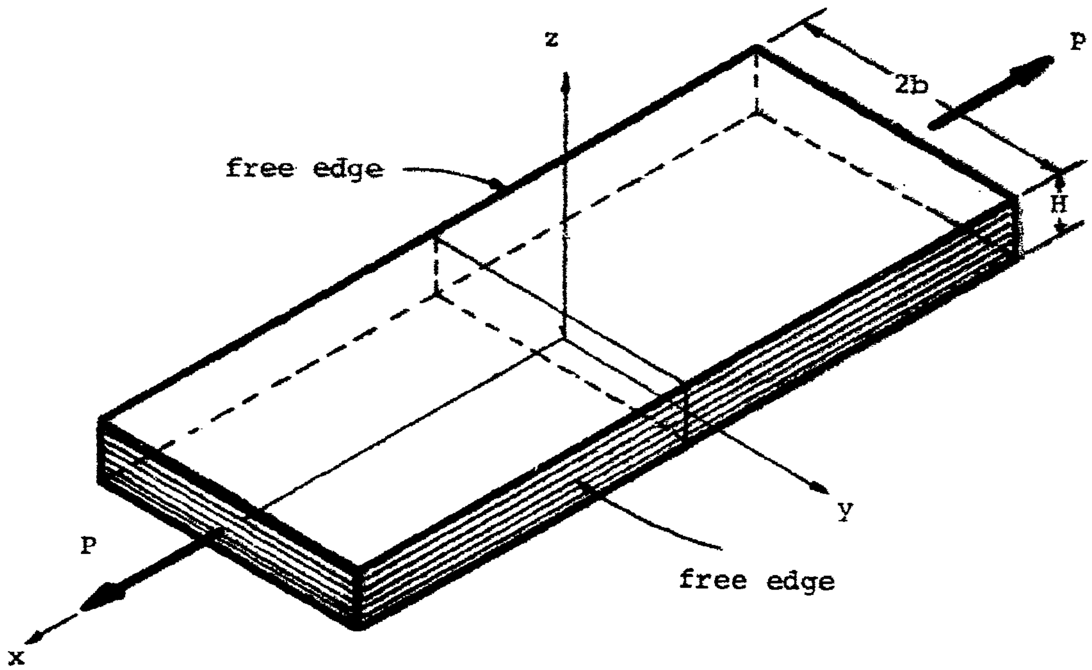


Figure A-4. Composite Tension Specimen.

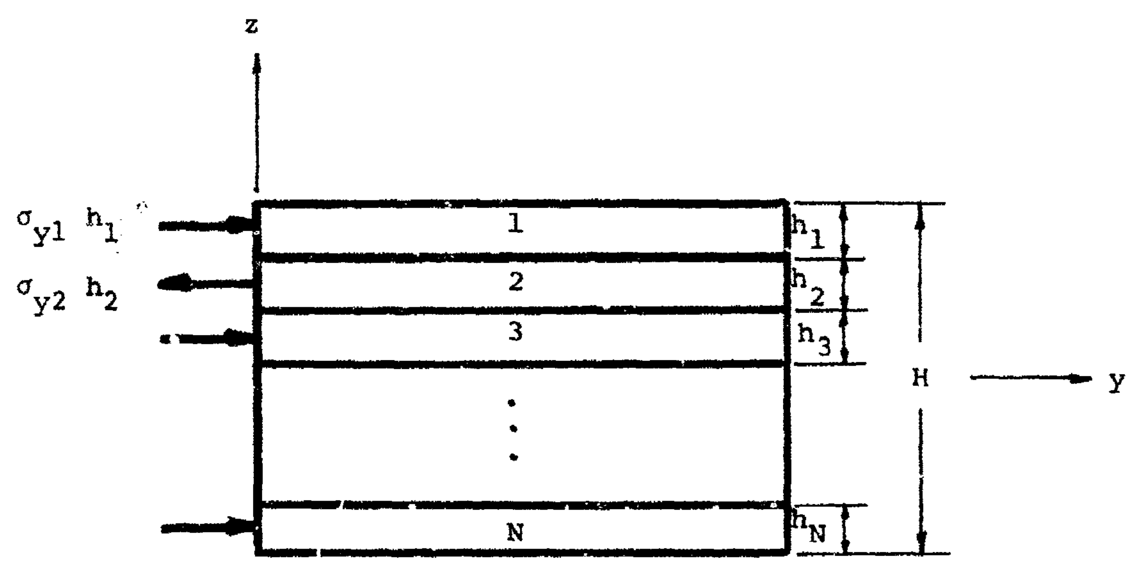


Figure A-5. Laminate Section at X = 0.

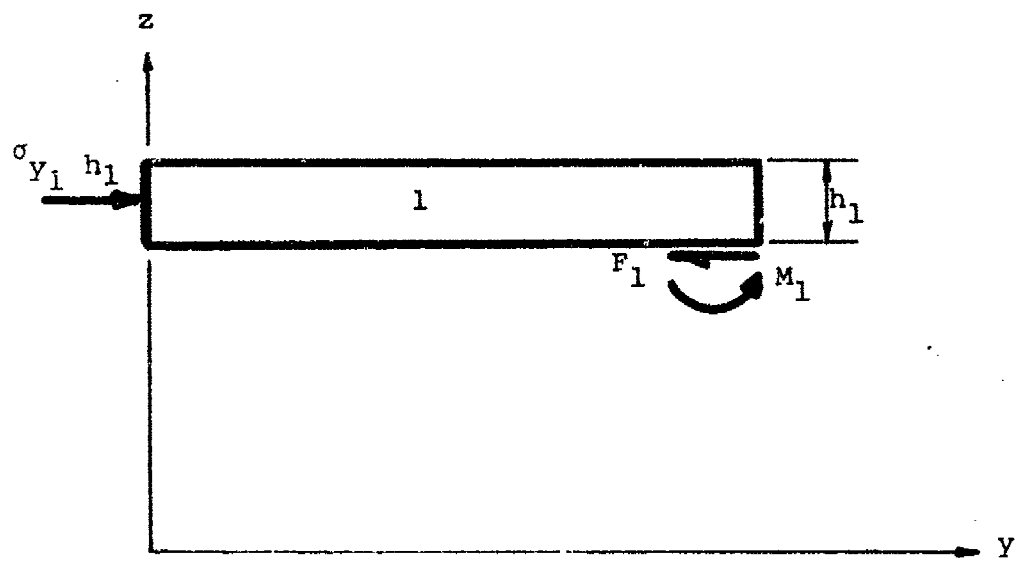


Figure A-6. Layer Number 1.

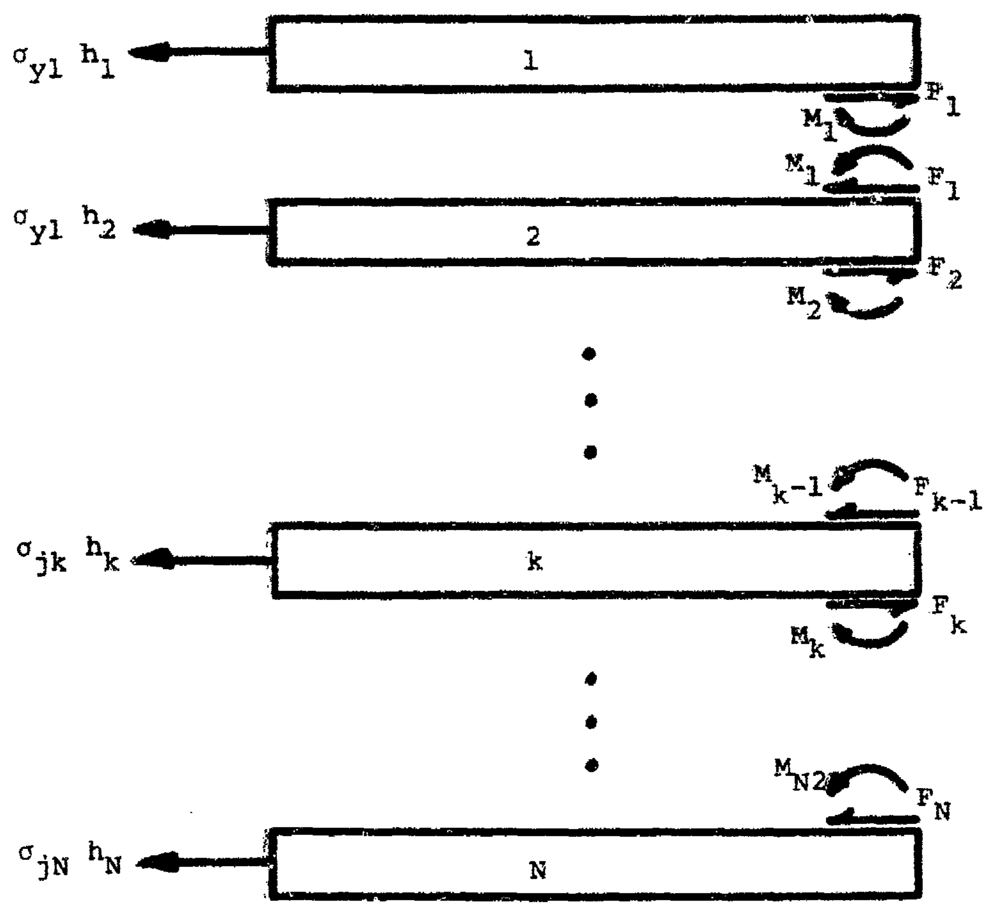


Figure A-7. Layer Edge Forces.

$$F_k = \sigma_k h_k + F_{k-1}$$

$$M_k = \frac{\sigma_k h_k^2}{2} + F_{k-1} h_k + M_{k-1} \qquad (A.14)$$

If these equations are applied sequentially starting with $k = 1$, for which $F_o = M_o = 0$, then each set of interlaminar forces can be determined in a recursive manner.

Now it is argued that the only way to develop edge moments near the free edge is to have a nonuniform distribution of interlaminar normal stress in that area. Such a normal stress is shown in Figure A-8, in which the distribution over a small length assures that the total moment of M_k, and the tension and compression areas balance. An approximate normal stress distribution (References 17-19) is shown in Figure A-9. Finally, using the approximate interlaminar normal stress distribution of Figure A-9, the following value is found for the normal stress at the free edge,

$$\sigma_{ek} = \frac{90}{7} \frac{M_k}{H^2} \qquad (A.15)$$

A.3 COMPUTATIONS FOR SPECIFIC LAMINATES

The analysis presented above has been utilized to estimate interlaminar normal stresses for seven specific laminates. The particular material systems and stacking sequences considered, along with their respective properties are listed in Table A-1.

The normal edge stresses developed in these composites are illustrated in Figure A-10. The five curves in the tensile half of the figure all have the same ply stacking sequence. The different tensile stress levels developed indicate the influence of material properties. The three curves for G-160/6535-1 graphite/epoxy illustrate the effects of different ply stacking sequences. Orientations (1) and (3) in Figure A-10

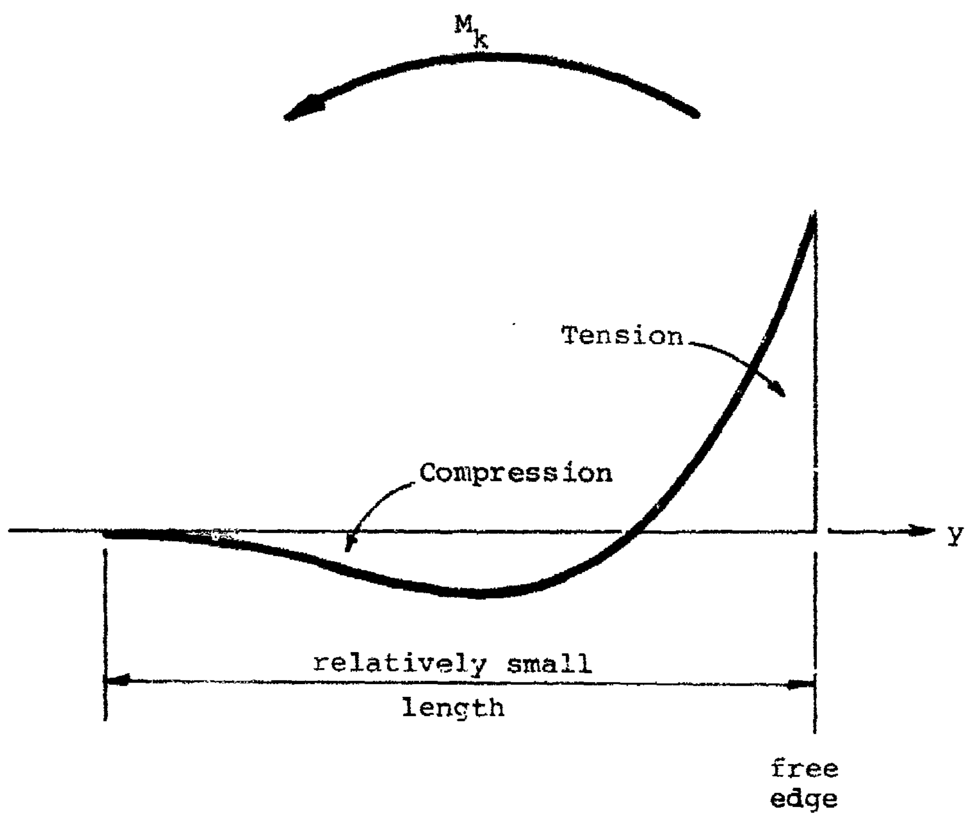


Figure A-8. Distribution of Normal Stress Near Free Edge.

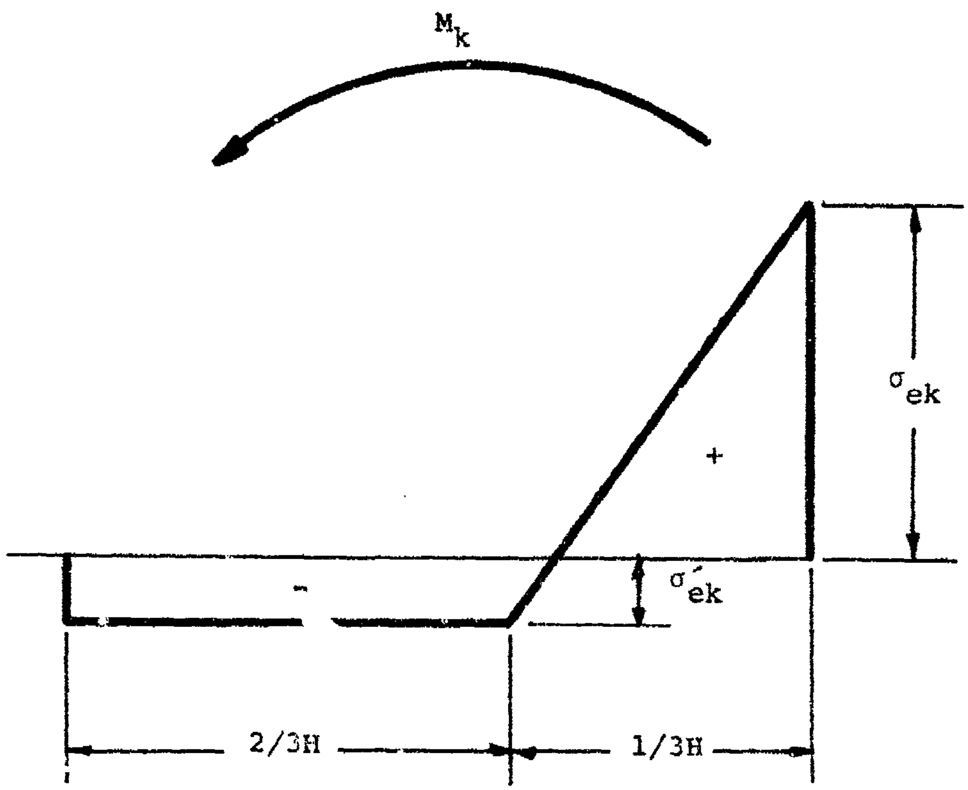


Figure A-9. Approximate Distribution of Interlaminar Normal Stress at Layer k.

TABLE A-1

LAMINATE SYSTEMS CONSIDERED IN SAMPLE INTERLAMINAR NORMAL STRESS ANALYSIS

	HyE 2034D	HyE 1076J	SiC/5506	T300/V378A	G-160/6535-1	G-160/6535-1	G-160/6535-1
t_{ply} (inch)	0.0049	0.0051	0.0064	0.0051	0.0048	0.0048	0.0048
E_1 (psi)	44.5×10^6	20.0×10^6	33.4×10^6	20.1×10^6	18.5×10^6	18.5×10^6	18.5×10^6
E_2 (psi)	0.97×10^6	1.34×10^6	2.99×10^6	1.31×10^6	1.82×10^6	1.82×10^6	1.82×10^6
G_{12} (psi)	0.73×10^6	0.92×10^6	0.74×10^6	1.62×10^6	0.95×10^6	0.95×10^6	0.95×10^6
ν_{12}	0.22	0.32	0.23	0.30	0.32	0.32	0.32
ply orientation	(1)	(1)	(1)	(1)	(1)	(2)	(3)

(1) $(0,45,-45,0,0,-45,45,0,90,0)_s$

(2) $(0,45,-45,0,0,-45,45,0)_s$

(3) $(0,90,45,-45,0,0,-45,45,0,0)_s$

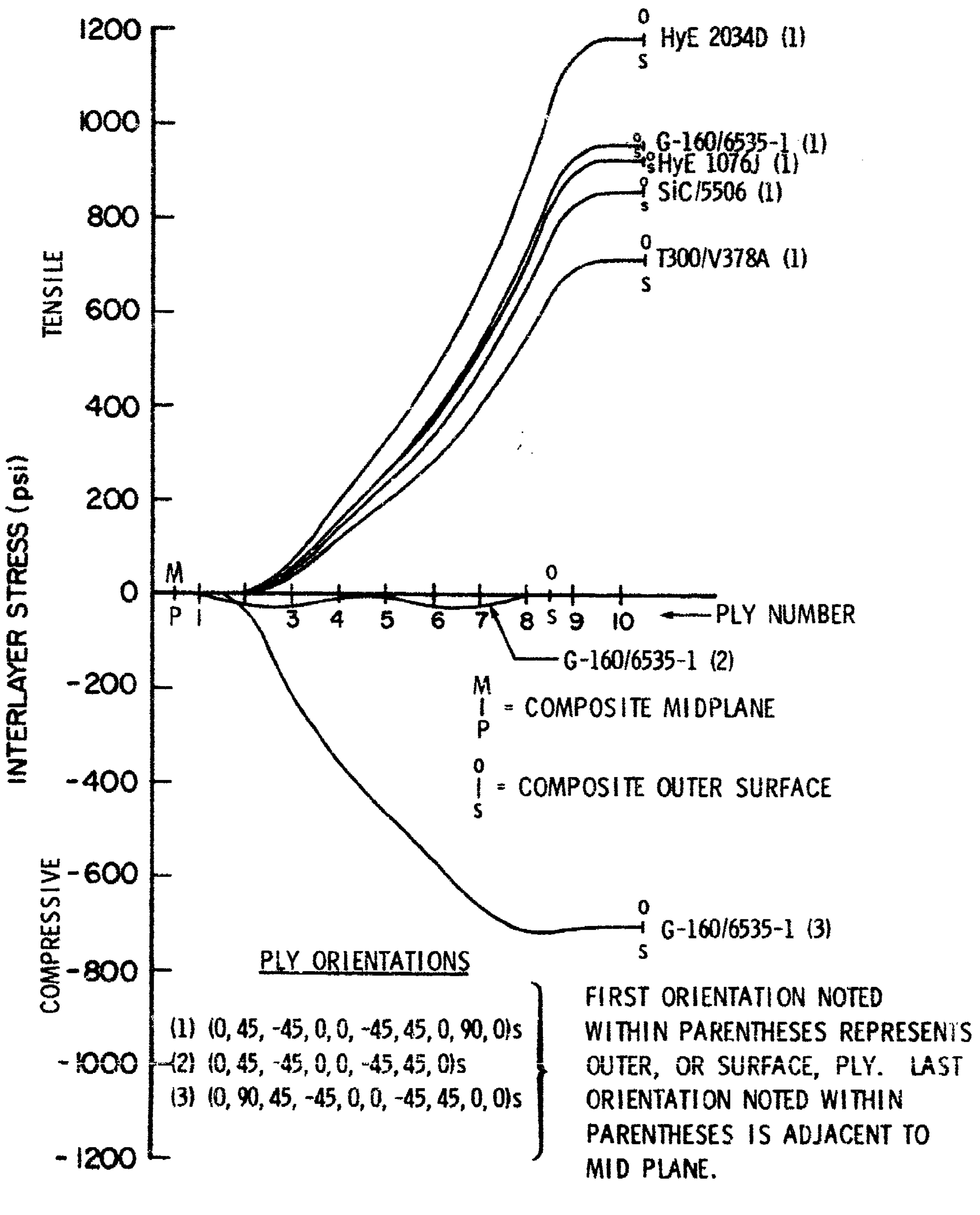


Figure A-10. Interlayer Normal Stresses for Various Composite Laminates.

differ only in the position of the 90° ply, while orientation (2) has no 90° ply and has one less 0° ply than orientations (1) and (3). All of the stresses plotted in Figure A-10 were computed for a stress resultant N_x = 1000 lb/in (1751 N/cm), as indicated in Equation (A.13).

APPENDIX B

PREPREG QUALITY CONTROL TEST PROCEDURES AND TEST RESULTS

This appendix contains copies of the test procedures followed in determining prepreg physical properties. It also presents the test results obtained from these various tests on each prepreg material. Summaries of these data are presented in Sections 4.1 through 4.6.

In addition to the tables of physical properties, chromatographic analyses are presented for resin extracted from each prepreg.

5.1.2 Test procedure. The test procedure shall be as follows:

a. Condition new Gooch filtering crucibles in beaker containing concentrated HNO_3 for a minimum of 1 hour at $100 \pm 5^{\circ}$ C. Wash with water, dry in oven at $93 \pm 3^{\circ}$ C and desiccate.

b. Weigh conditioned filtering crucible to the nearest 0.1 milligram (mg).

c. Carefully remove release paper from prepreg specimen and place specimen in tared crucible.

d. Weigh crucible containing specimen to the nearest 0.1 mg.

e. Condition crucible and specimen in an oven maintained at $93.5^{\circ} \pm 3^{\circ}$ C for a minimum of 90 minutes and a maximum of 120 minutes, unless otherwise specified in the applicable prepreg specification.

NOTE

Prepregs with polyimide resin systems should be conditioned at $288 \pm 3^{\circ}$ C for 60 ± 1 minutes.

f. Remove crucible from oven, cool to room temperature in a desiccator, and reweigh.

g. Calculate volatiles content of prepreg as follows:

$$\text{Weight \% Volatiles} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

where: W_1 = weight of empty conditioned filtering crucible, grams (g)

W_2 = original weight of crucible and specimen before heating, g

W_3 = final weight of crucible and specimen after heating, g

5.2.3 Procedure C (hot MEK extraction method). Determine resin content of prepreg by the hot MEK extraction method as follows:

a. Prepreg samples shall be as specified in table I. Take duplicate test specimens, one from each end of the sample.

Table I. Resin Content Specimens for Procedures C, D, and E

Tape width	Sample size
3 inches	3 inches by 3 inches
6 inches	2 inches by 6 inches
12 inches	1 inch by 12 inches

b. Weigh clean filtering crucible to the nearest 0.1 mg.

c. Carefully remove release paper from the prepreg specimens and place in tared crucible.

d. Weigh crucible containing specimen to the nearest 0.1 mg.

e. Add 150 ml MEK to a 250 ml beaker, place beaker on a steam bath and bring to a boil. (Beaker should be covered with a watch glass to minimize evaporation.)

f. Add prepreg sample to the hot MEK, being careful not to splash the hot MEK. Stir occasionally and let heat for ten minutes or until MEK boils.

g. Transfer the MEK and fiber into the original tared filtering crucible positioned in a filtering flask with vacuum trap and vacuum pump.

h. Wash the fiber three times with additional hot MEK.

i. Remove the crucible containing fibers and dry in an oven maintained at $163^\circ \pm 3^\circ$ C for 15 to 20 minutes.

j. Remove crucible from oven, cool in a desiccator, and weigh to the nearest 0.1 mg.

k. Calculate resin content as follows:

$$\text{Weight \% Resin} = \left[\frac{W_2 - W_3}{W_2 - W_1} \times 100\right] - V$$

where: W_1 = weight of empty crucible, g

W_2 = original weight of crucible and specimen, g

W_3 = final weight of crucible and fibers, g

V = weight percent volatiles from 5.1, %

5.3.2 Procedure B. Determine resin flow as follows:

a. Cut eight 4 x 4 inch plies of sample prepreg.

b. Lay up the prepreg plies $0^{\circ}/90^{\circ}$ and weigh to the nearest 0.1 g.

c. Place layup on 1/4 inch thick aluminum plate which has been covered with nonporous teflon.

d. Cut one 6 x 6 inch ply of porous TFE release cloth and place on top of layup.

e. Cut two 6 x 6 inch plies of glass bleeder cloth and place on top of TFE release cloth.

f. Cover entire layup with 1 ply of glass bleeder cloth to be used as air breather.

g. Place entire assembly in vacuum bag.

h. Place in oven at room temperature and pull full vacuum (25 inches Hg).

i. Bring oven up to 250°F (oven temperature) in 30 to 45 minutes and hold at 250°F for 30 minutes while maintaining full vacuum.

j. Raise temperature to 350°F (oven temperature) in 30 to 45 minutes and hold at 350°F for 60 minutes.

k. Remove from oven while hot and remove from vacuum bag.

l. Clean any excess resin from panel.

m. Weigh panel to the nearest 0.1 g.

n. Calculate the resin flow as follows:

$$\text{Resin flow, percent} = \frac{W_1 - W_2}{W_1} \times 100$$

where: W_1 = original weight of prepreg layup, g.

W_2 = final weight of panel, g.

o. Report the average of a minimum of two determinations.

Hercules Specification
Gel Time

HD-SG-2-6006C

5.5 Gel time. The prepreg gel time shall be determined as follows:

5.5.1 Specimen preparation. Prepare specimen for gel time test as follows:

a. Cut 12 to 13 prepreg strips 3/4-inch by 3-inch (4 to 5 grams) and stack strips on top of each other. Roll stacked prepreg strips to form an approximately 3/4-inch by 3/4-inch diameter cylinder as shown in figure 2.

b. Place prepared specimen on one end of approximately 3-1/2 inch by 7-inch x 0.006 inch aluminum foil and roll tightly. Fold open ends tightly over the middle and cut one corner with scissors to make approximately 1/16 inch opening. (See figure 3.)

5.5.2 Equipment preparation. Prepare equipment for gel time testing as follows:

a. Place bottom gel plate (figure 4) 1/4-inch from front center of bottom press platen and tape down with three-inch wide green pressure sensitive tape.

b. Place top gel plate (figure 4) against top press platen and center directly over bottom gel plate as shown in figures 5 and 6. Tape top gel plate in place with green pressure sensitive tape.

c. Place a thermocouple on the center of bottom gel plate, 3/4-inch from the front end and as shown in figure 3. Stabilize at test temperature specified in the applicable prepreg specification.

5.5.3 Test procedure. The gel time test procedure shall be as follows:

a. Place thermocouple on bottom gel plate, 3/4-inch in from the front edge of the plate and 1-1/2 inches from either left or right edge as shown in figure 5. Use green pressure sensitive tape to secure the thermocouple wire so that the thermocouple will remain in the intended position.

b. Place gel specimen on bottom gel plate so that the cut corner is positioned 1/8 to 1/4 inch behind thermocouple and facing the operator.

c. Close the press platen quickly and apply sufficient pressure to obtain approximately 1/4 inch resin bead. Start timing at this point. The total elapsed time from the time specimen is placed on gel plate to closing platens should be 15 ± 5 seconds.

d. Using a wooden probe, probe the edges of the resin bead. As gel time approaches, the resin becomes quite viscous and forms a string as the wooden probe is moved away from the resin. Continue probing until the resin ceases to string and the resin mass becomes no longer plastic. At this point the resin mass should form permanent deformation when pressed with the tip of the wooden probe. Note the elapsed time and record the time and the test temperature.

e. Report the average of a minimum of two determinations.

4.2.3.2 RESIN CONTENT

4.2.3.2.1 Graphite

One 2-inch-square specimen with volatiles removed is placed in a 150 to 250 ml beaker. The beaker is filled with 100 ml of nitric acid (HNO_3) and placed on a hot plate maintained at 100° C ±5° C (212° F). The sample is digested until fiber is completely separated as determined by visual examination. The acid and fibers are transferred into a tared glass filtering crucible positioned in a filtering flash with vacuum trap and vacuum pump. Fibers are washed three times with 20 ml of HNO_3 and followed by water wash.

The crucible and fibers are dried at 93.5° C ±3° C (200° F) for a minimum of 60 minutes, cooled in a desiccator, and the weight (W_4) is obtained. The weight percent of resin is computed from:

$$\text{Resin content w/o} = \frac{W_3 - W_4}{W_2 - W_1} (100)$$

where

W_1 = is crucible weight

W_2 = is sample and crucible weight

W_3 = is specimen weight

W_4 = is weight after acid digest (fibers)

Compute weight percent of fiber from:

$$\text{Fiber content w/o} = \frac{W_4 - W_1}{W_2 - W_1} (100)$$

4.2.3.3 VOLATILE CONTENT

The following procedure is applicable to both graphite and boron prepreg. Filtering crucibles are conditioned in a beaker containing concentrated nitric acid (HNO_3) for a minimum of 1 hour at 100° C ±5° C (212° F). The crucible is washed, desiccated, and weighed (W_1). A 2-inch-square prepreg sample is placed in the crucible and weighed (W_2). Prepregs with epoxy resin systems are conditioned in a nonrecirculating oven maintained at 93.5° C ±3° C (200° F) for a minimum of 90 minutes and a maximum of 120 minutes. The crucible is removed from the oven, desiccated, and reweighed (W_3). The weight percent of volatiles is obtained from

$$\text{Volatiles w/o} = \frac{W_2 - W_3}{W_2 - W_1} (100)$$

Data are averaged from a minimum of three tests.

QUALITY CONTROL METHOD QCI-C-V-14

Fiberite Specification

VOLATILE CONTENT OF GRAPHITE PREPREG

1. Place a 2" x 2" sample into previously weighed Aluminum pan (W_2). Sample must lay flat and cannot be rolled up or more than one ply thick.
2. Weigh sample and pan to the nearest milligram (W_1).
3. Place into a forced air oven maintained at 163±3°C for 20±0.5 minutes.
4. Cool to room temperature in a desiccator and weigh to the nearest milligram (W_3).
5. Calculate as follows:

$$\text{Volatile content, percent} = \frac{W_1 - W_3}{W_1 - W_2} \times 100$$

W_1 = weight of pan plus specimen before volatile removal.

W_2 = weight of pan.

W_3 = weight of pan plus specimen after volatile removal.

QUALITY CONTROL METHOD R-15

Fiberite Specification

RESIN SOLIDS CONTENT OF GRAPHITE PREPREG

SCOPE: This method is applicable for the determination of percent resin solids in unfilled carbon or graphite prepreg roving or tape material where this method has been found suitable or is called out in a specification.

PROCEDURE:

1. Run volatile content on a sample cut adjacent to the sample to be used for resin solids. The volatile procedure used shall be as specified in the material specification.
2. Cut a sample of material approximately 3 grams in any convenient size.
3. Weigh the sample to the nearest 0.0001 gram. Record this as W_1
4. Place the sample in a 400 ml beaker. Add 200 ml of DMF (Dimethyl formamide). Boil for 5 minutes (time starts when the DMF starts to boil).
5. Cool sample. Pour off the DMF. Wash sample twice with acetone.
6. Place sample in a tared aluminum foil pan. Dry sample for 30 minutes in an oven maintained at $163 \pm 3°C$.
7. Cool sample to ambient temperature in a desiccator.
8. Reweigh the sample to the nearest 0.0001 gram. Record the weight as W_2.

CALCULATION: Resin Solids (% by weight) =

$$\frac{(W_1 - W_1 V) - W_2}{(W_1 - W_1 V)} \times 100$$

Where: W_1 = Original sample weight.

W_2 = Weight of carrier remaining after extraction.

V = Percent volatiles (Procedure as called out by the material specification).

QUALITY CONTROL METHOD QCI-C-F-42

Fiberite Specification

FLOW OF GRAPHITE PREPREG

Flow:	Laminate
Form:	2 ply 2" x 2" square cut
Lay-up:	Cut 6 pieces of style 1581 glass bleeder cloth, 4" x 4" square and 2 pieces of pourous teflon separator cloth (EMFAB TX-1040 or equivalent) 4" x 4" square. Weigh all to the nearest milligram (W_1). Cut 2 pieces of prepreg 2" x 2", cross ply 0° and 90°, and assemble as follows: 3 pieces 1581 glass, 1 piece porous teflon, 2 pieces graphite prepreg (cross plied 0° and 90°), 1 piece porous teflon, 3 pieces 1581 glass, and weigh to the nearest milligram (W_2).
Temperature:	325 ± 5°F
Pressure:	100 psi (400# total pressure)
Time:	15 ± 1 minute
Determination:	As required
Procedure:	Put Mylar release film on both sides of Lay-up and place into 325°F preheated press. Apply 100 psi for 15 minutes. Remove and discard Mylar film. Remove crossplied test specimen and weigh 1581 glass and porous teflon to nearest milligram (W_3).
Calculation:	$\text{Flow, \%} = \frac{W_3 - W_1}{W_2 - W_1} \times 100$

W_1 = Weight of 1581 glass fabric and porous teflon separator

W_2 = Weight of 1581 glass fabric, porous teflon separator and cross plied specimen.

W_3 = Weight of 1581 glass fabric and porous teflon separator after cure.

QUALITY CONTROL METHOD G-2

Fiberite Specification

GEL TIME

Gel time of graphite prepreg tape or broadgoods materials.

SCOPE: This method is applicable for the determination of gel time on carbon or graphite prepreg materials containing a thermosetting resin which undergoes gelation at a specified temperature.

APPARATUS

1. Fisher-Johns melting point apparatus
2. Thickness No. 2 cover glasses (18 mm)
3. Timer or stopwatch
4. Wooden picks

PROCEDURE

1. Preset the Fisher-Johns melting point apparatus to read ± 1 C of the specified temperature.
2. Insert a ¼" x ¼" sample between 2 cover glasses and place on the Fisher-Johns apparatus.
3. Start the timer and probe the specimen with a wooden pick.
4. When resin gels (this is usually evident when no resin movement is seen when moderate pressure is applied to the specimen) stop the timer and report the gel time to the nearest 0.1 minute
5. Report the gel time as the average of three determinations.

GEL TEMPERATURES FOR GRAPHITE PREPREG

RESIN SUFFIX	TEST TEMPERATURE (°C)
-48	121
-30	170 C
-34	163 °C (32[illegible] °F)

Example

hy-E 1348-B — Resin Suffix   Run at 121 C

PREPREG PHYSICAL PROPERTIES				
Material: T300/AFR800			Vendor: Hexcel	
Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Resin Flow (% by wt)
22300	1	0.26	41.95	14.91
22300	1	0.32	41.43	12.59
22300	1	0.32	42.99	14.19
Lot/Batch Number	Spool/Roll Number	Gel Time @ 275°F (135°C) (minutes)		
22300	1	141		
22300	1	142		
22300	1	141		
	Received:	Tested:	Remarks	
Spool #1	11-20-78	11-21-78	Volatiles, Resin Content, Flow	
		12-18-78	Gel Time	

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	HD-SG-2-6006C (5.1.2)	Hercules
Resin Content	HD-SG-2-6006C (5.2.3C)	Hercules
Resin Flow	HD-SG-2-6006C (5.3.2B)	Hercules
Gel Time	HD-SG-2-6006C (5.5)	Hercules

PREPREG PHYSICAL PROPERTIES				
Material: T300/AFR800			**Vendor:** Hexcel	
Lot/Batch Number	**Spool/Roll Number**	**Volatile Content (% by wt)**	**Resin Content (% by wt)**	**Resin Flow (% by wt)**
22300	2	0.18	41.54	15.49
22300	2	0.07	39.73	15.52
22300	2	0.07	39.11	15.53
Lot/Batch Number	Spool/Roll Number	Gel Time @ 275°F(135°C) (minutes)		
22300	2	140		
22300	2	139		
22300	2	141		
	Received:	Tested:	Remarks	
Spool #2	11-30-78	12-1-78	Volatiles,Resin Cont.,Flow	
		12-13-78	Gel Time	

Test Procedures Followed

Property	**Applicable Test Spec.**	**Source of Test Spec.**
Volatile Content	HD-SG-2-6006C (5.1.2)	Hercules
Resin Content	HD-SG-2-6006C (5.2.3C)	Hercules
Resin Flow	HD-SG-2-6006C (5.3.2B)	Hercules
Gel Time	HD-SG-2-6006C (5.5)	Hercules

PREPREG PHYSICAL PROPERTIES (1)				
Material: T300/AFR800			Vendor: Hexcel	
Lot/Batch Number	Spool/Roll Number	Test Date	Gel Time (minutes)	Resin Flow (% by wt)
22300	1	1-3-79	---	21.7
22300	1	1-8-79	152	---
22300	2	1-4-79	---	19.3
22300	2	1-10-79	140	---
22300	2	1-19-79	---	21.9

(1) These tests were conducted to determine the effect of room temperature storage on prepreg properties.

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content		
Resin Content		
Resin Flow	HD-SG-2-6006C(5.3.2B)	Hercules
Gel Time	HD-SG-2-6006C (5.5)	Hercules

PREPREG PHYSICAL PROPERTIES				
Material: SiC/5506			Vendor: AVCO	
Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Resin Flow (% by wt)
2	1	1.38	29.38	---
2	1	1.38	28.20	---
2	1	1.49	27.25	---
2	4	---	26.68	---
2	4	1.48	27.13	---
2	4	1.56	28.28	---
2	2B	1.32	26.86	---
2	2B	1.27	26.95	---
2	2B	1.42	28.48	---
2	2A	1.28	28.49	---
2	2A	1.42	28.84	---
2	2A	---	28.37	---

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	Section 4.2.3.3	Advanced Composites Design Guide,
Resin Content	Section 4.2.3.2.1	Jan. 1973, Vol. IV
Resin Flow	---	---

HPLC ANALYSIS

SAMPLE (CONC.) AVCO 5506 SAMPLE SIZE 1.5 mg/ml

MOBILE PHASE 1 ACETONITRILE MOBILE PHASE 2 WATER

FLOW RATE 2.0 ml/min PROGRAM METH. 0

COLUMN(S) ODS DETECTOR TRACOR 970

ATTENUATION 32 WAVE LENGTH 230 nm

CHART SPEED 0.5 cm/min FULL SCALE (mV) 20 mV

DATE NOVEMBER 28 79 OPERATOR WOLFE

TIME 0	WATER	76%	ACETO.	24%
20 MIN		18%		82%
21 MIN		1%		99%

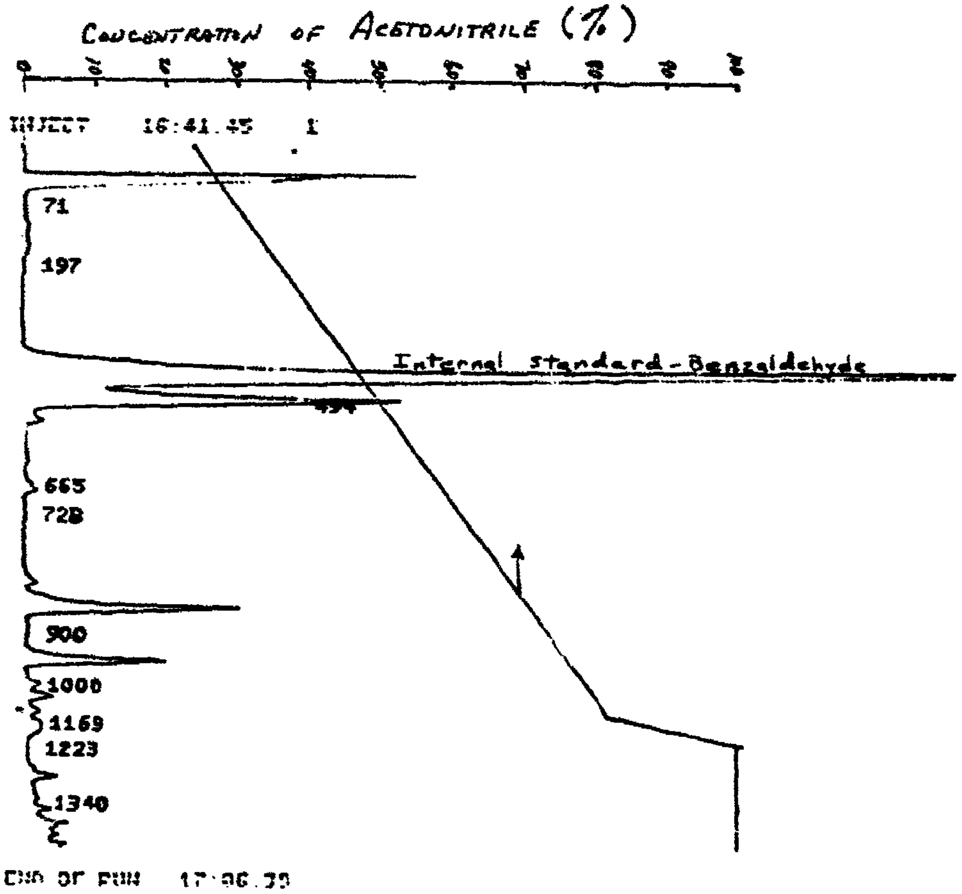


Figure B-1. HPLC Analysis of AVCO 5506 Epoxy Resin.

PREPREG PHYSICAL PROPERTIES				
Material: HyE 2034D			Vendor: Fiberite	
Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Resin Flow (% by wt)
C0-010	1	0.62	39.05	22.35
		0.69	38.33	26.68
		0.69	40.16	26.35
Lot/Batch Number	Spool/Roll Number	Gel Time @ 325°F(163°C) (minutes)		
C0-010	1	12.63		
		12.48		
		12.23		

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	QCI-C-V-14	Fiberite
Resin Content	R-15	Fiberite
Resin Flow	QCI-C-F-42	Fiberite
Gel Time	G-2	Fiberite

HPLC ANALYSIS

SAMPLE (CONC.)	HYE-2034D	SAMPLE SIZE	1.5 mg/ml
MOBILE PHASE 1	Acetonitrile	MOBILE PHASE 2	Water
FLOW RATE	2.0 ml/min	PROGRAM	Method [illegible]
COLUMN(S)	ODS	DETECTOR	Tracor 970
ATTENUATION	32	WAVE LENGTH	230 nm
CHART SPEED	0.5 cm/min	FULL SCALE (mV)	2.0 mV
DATE	November 30 79	OPERATOR	Wolfe

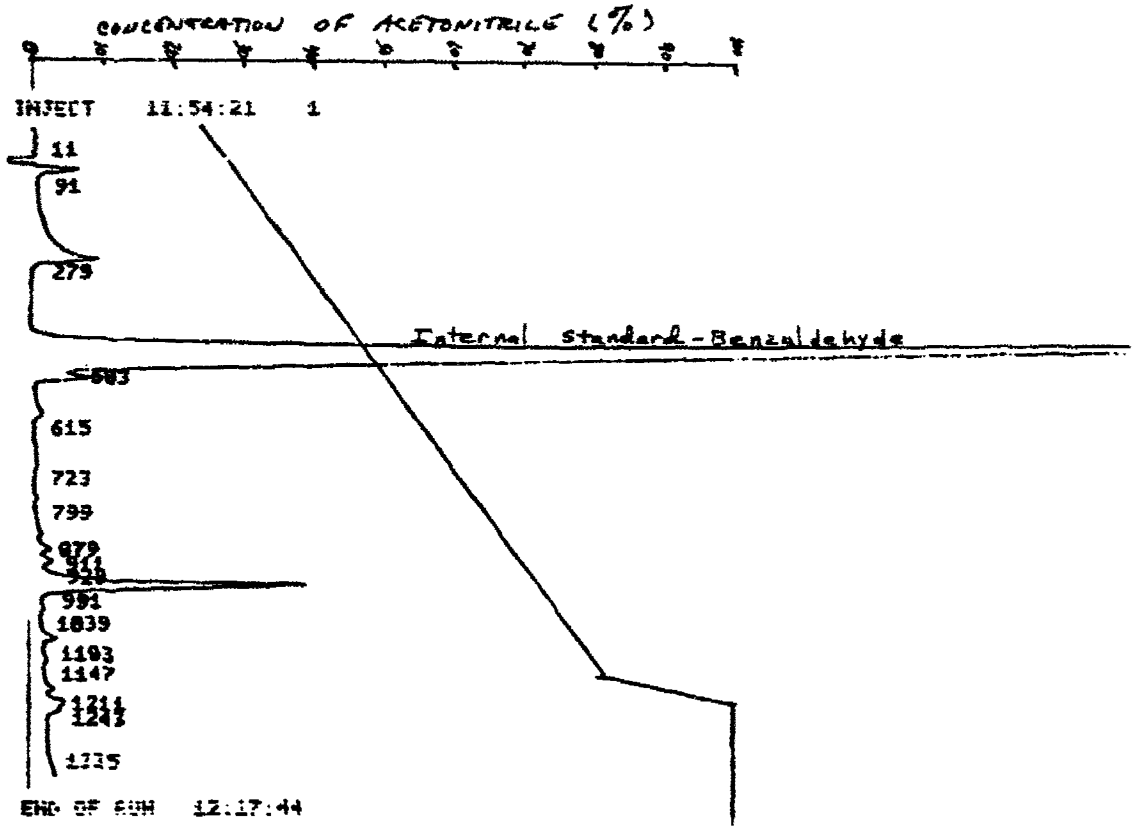


Figure B-2. HPLC Analysis of Fiberite 934 Epoxy Resin.

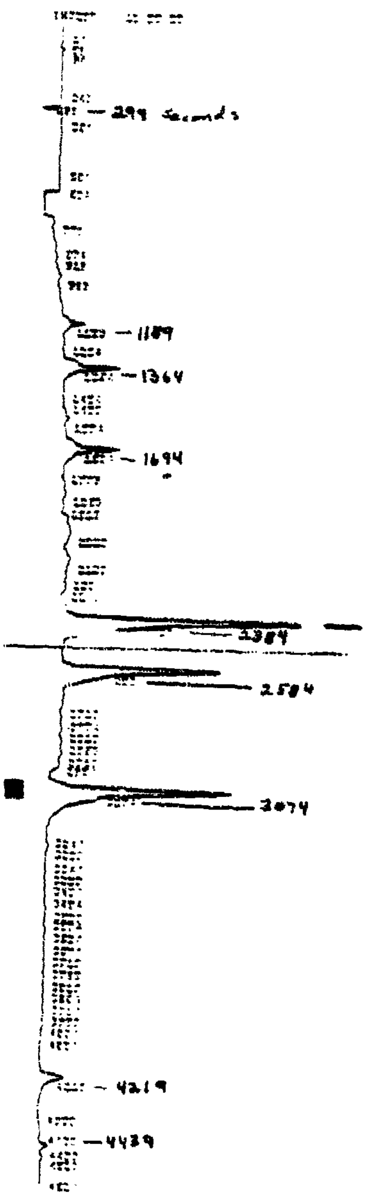
PREPREG PHYSICAL PROPERTIES				
Material: T300/V378A			Vendor: U.S. Polymeric	
Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Gel Time @ 210°F(99°C) (minutes)
2W4810	1	5.79	29.00	30.52
		6.05	30.28	32.03
		4.61	32.63	31.97
2W4683	1	2.5[1]	31.3[1]	

[1]All data on Batch No. 2W4683 was generated by USP.

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	OCI-C-V-14[2]	Fiberite
Resin Content	R-15	Fiberite
Gel Time	G-2	Fiberite

[2]Test conducted at 350°F (177°C) for 5 minutes rather than 325°F (163°C) for 20 minutes as called for in step 3 of specification.



HPLC ANALYSIS

V378A - New*

SAMPLE (CONC.) 0.1% SAMPLE SIZE 25 ul

MOBILE PHASE 1 H_2O MOBILE PHASE 2 Dioxane

FLOW RATE 1.0 ml/min PROGRAM Meth 0

COLUMN(S) RP-8 (SP) DETECTOR Tracor-UV

ATTENUATION 16 WAVE LENGTH 254

CHART SPEED .5 cm/min FULL SCALE (mV) 40

DATE 10-2-80 OPERATOR B. Price

* 1 month storage at 0°F

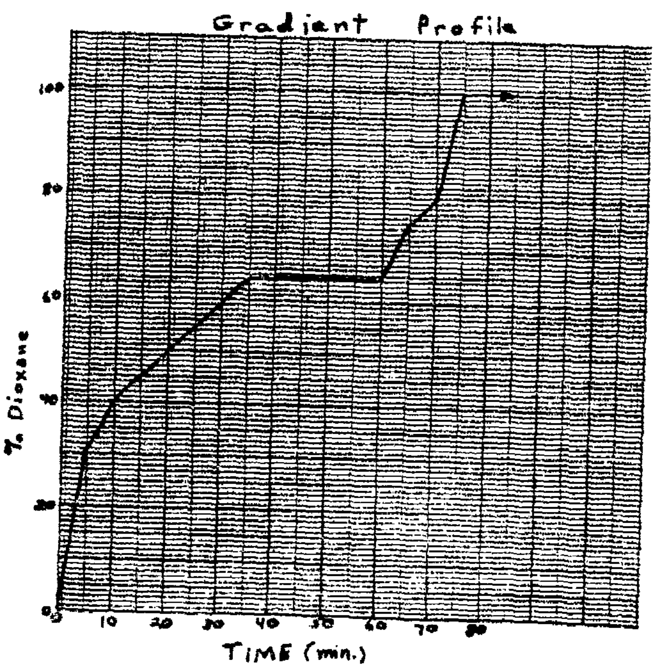


Figure B-3. HPLC Analysis of New U.S. Polymeric V378A Polyimide Resin.

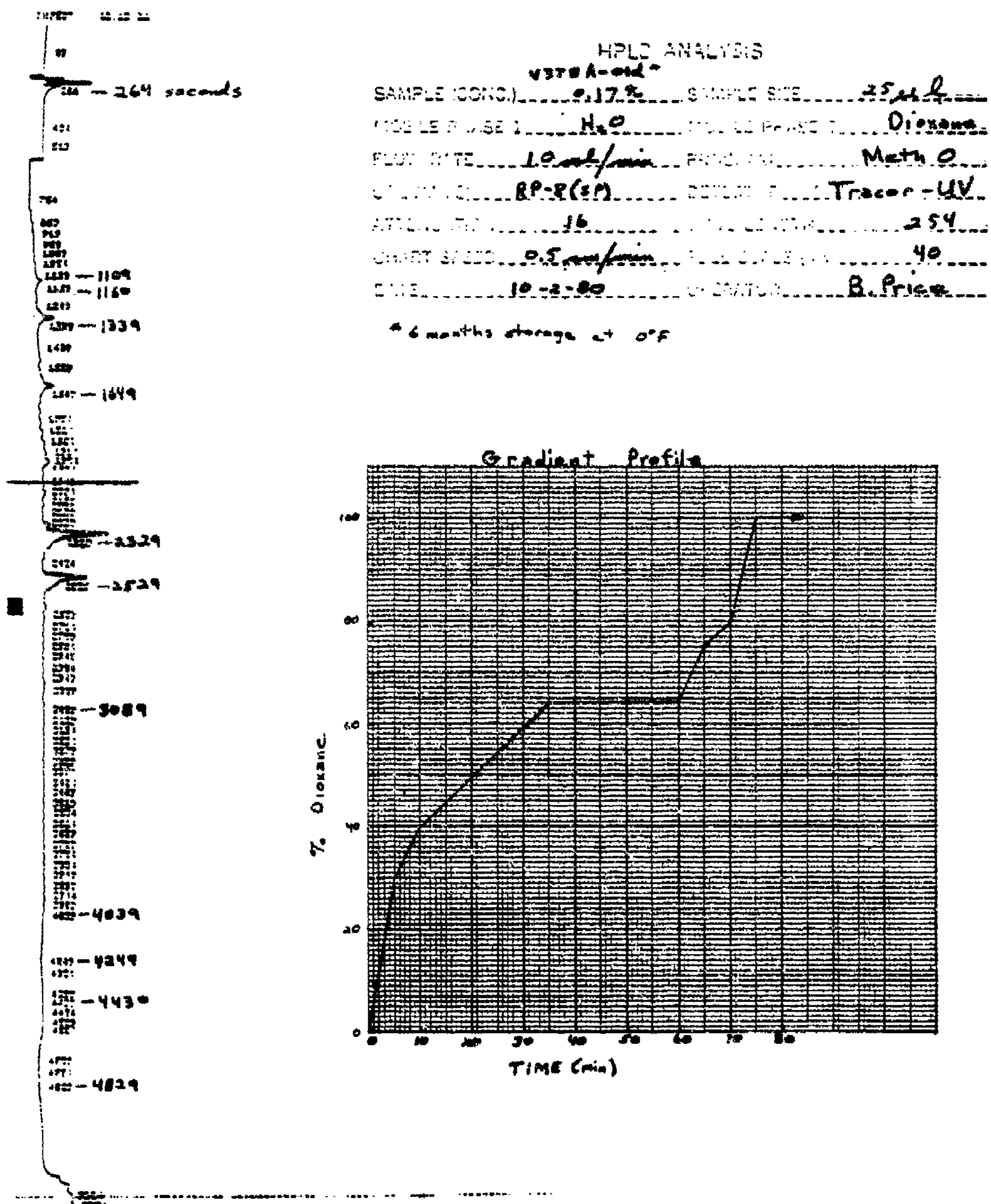


Figure B-4. HPLC Analysis of Old U.S. Polymeric V378A Polyimide Resin.

PREPREG PHYSICAL PROPERTIES

Material: HyE 1076J			Vendor: Fiberite	
Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Gel Time[1] (min)
C1-285	1	0.57	37.77	21.4
C1-285	1	0.51	37.84	20.1
C1-285	1	0.23	37.46	22.3

[1]at 177°C

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	QCI-C-V-14	Fiberite
Resin Content	Method-R-15	Fiberite
Gel Time	Method-G-2	Fiberite

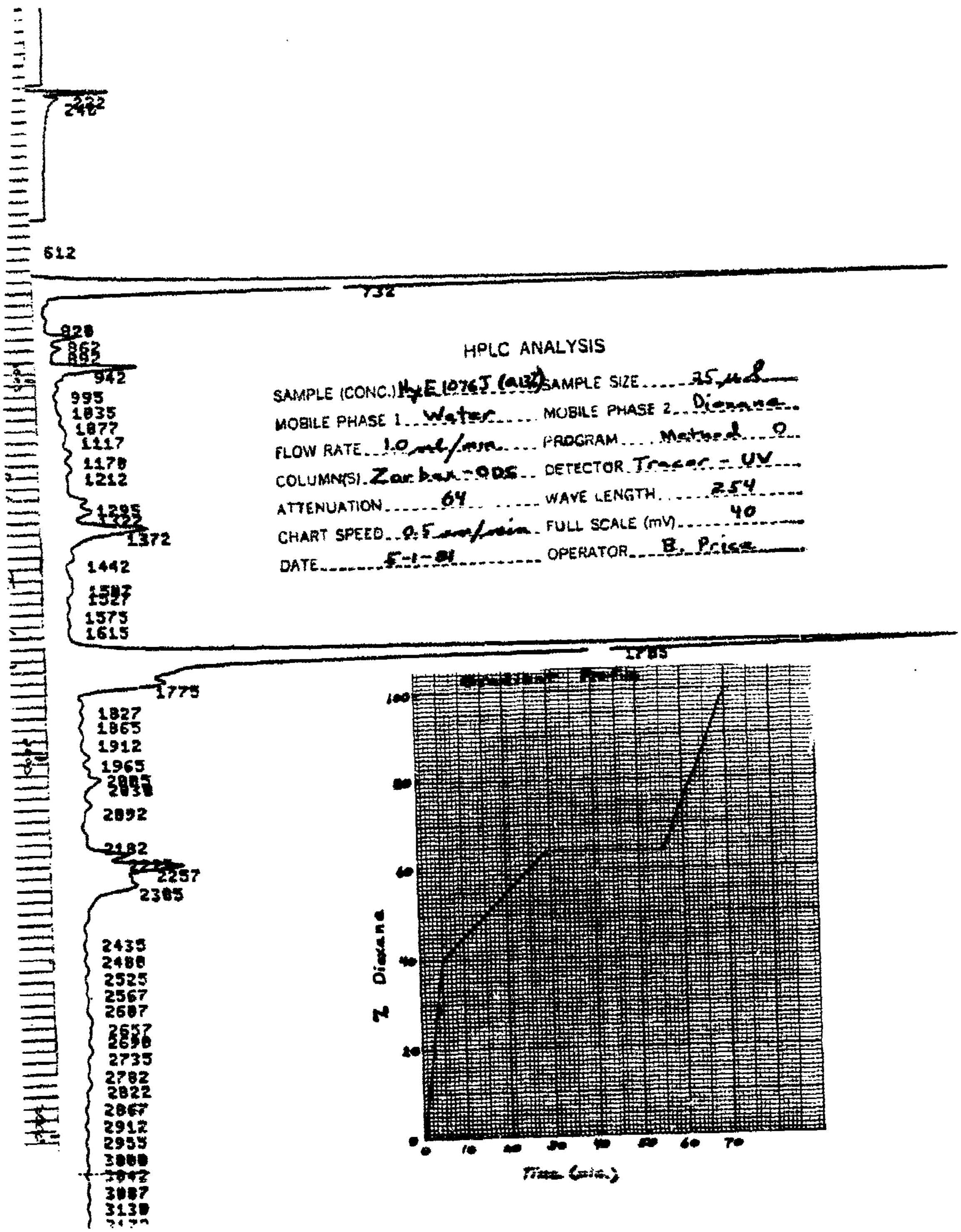


Figure B-5. HPLC Analysis of Fiberite 976 Epoxy Resin.

PREPREG PHYSICAL PROPERTIES				
Material: G-160/6535-1			Vendor: AVCO	
Lot/Batch Number	Spool/Roll Number	Volatile Content (% by wt)	Resin Content (% by wt)	Gel Time @ 327°F (164°C) (minutes)
	440	0.23	39.27	38.49
		0.22	41.58	37.21
		0.14	40.82	38.55
	441	0.28	42.77	38.68
		0.13	40.73	37.75
		0.22	44.09	38.30

Test Procedures Followed

Property	Applicable Test Spec.	Source of Test Spec.
Volatile Content	QCI-C-V-14	Fiberite
Resin Content	R-15	Fiberite
Gel Time	G-2	Fiberite

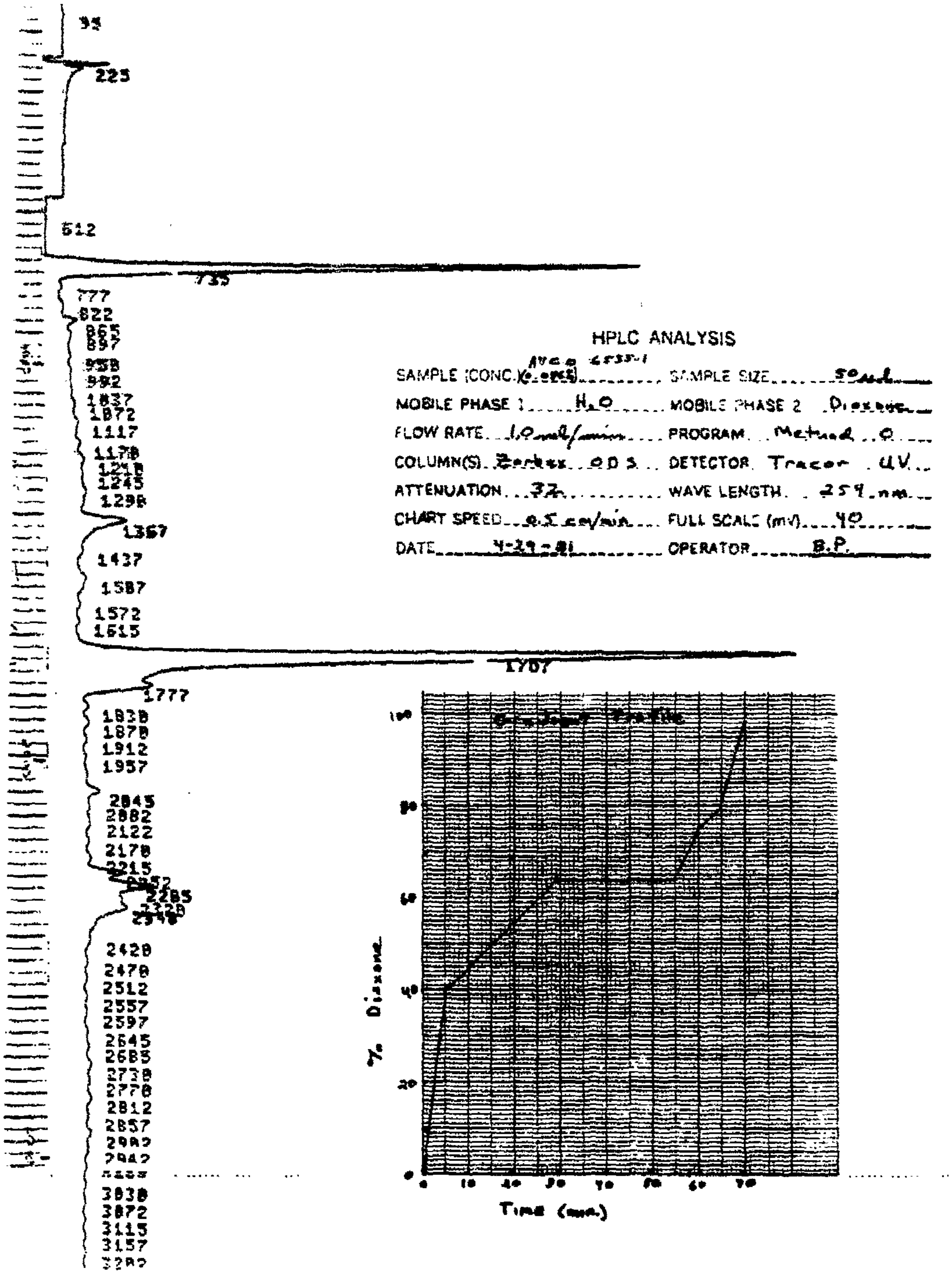


Figure B-6. HPLC Analysis of AVCO 6535-1 Epoxy Resin.

APPENDIX C
LAMINATE PHYSICAL PROPERTY DATA

All of the physical property measurements conducted upon the panels fabricated and used in this program are presented here. Summaries of these data appear in Sections 4.1 through 4.6.

LAMINATE PHYSICAL PROPERTIES

Material: T300/AFR800

Lam. No.	Fiber Orient.	No. Plies	Spec. Grav.	Resin Content (% by wt)	Fiber Content (% by vol)	Void Content (% by vol)	Thick. per ply (10^{-3} in.)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
F1	0°	6	1.60	24.4	71.2	0.0		22300	1
F3	0°	6	1.64	25.4	72.0	0.0		22300	1
F4	0°	6	1.60	25.2	70.4	0.0		22300	1
F5	0°	6	1.65	25.3	72.5	0.0		22300	1
F6	0°	6	1.58	31.8	63.4	0.0		22300	1
F7	0°	15	1.59	24.4	70.7	0.0		22300	1
F8	0°	15	1.62	25.0	71.4	0.0		22300	1
F9	0°	15	1.61	25.4	70.7	0.0		22300	1
F11	90°	15	1.60	25.0	70.6	0.0		22300	1
F12	90°	15	1.56	25.3	68.6	0.0		22300	1
F13	90°	15	1.62	24.9	71.5	0.0		22300	1
F14	90°	15	1.62	24.2	72.2	0.0		22300	1
F15	90°	15	1.62	24.5	72.0	0.0		22300	1
F16	90°	15	1.54	24.6	68.3	1.1		22300	1
F17	90°	15	1.61	24.3	71.7	0.0		22300	1
F18	90°	15	1.62	24.1	72.2	0.0		22300	1
F19	0°	14	1.67	24.1	73.9	0.0		22300	1
F20	90°	14	1.71	23.5	77.0	0.0		22300	1
F21	0°	15	1.62	24.0	72.5	2.5		22300	1
F22	0°	6	1.58	25.9	68.8	0.0		22300	1
F23	±45°	8	1.57	30.7	64.0	0.0		22300	1
F24	±45°	8	1.54	31.1	62.4	0.0		22300	1
F25	±45°	8	1.60	29.9	66.1	0.0		22300	1
F26	±45°	8	1.56	30.8	63.4	0.0		22300	1
F27	±45°	8	1.57	30.1	64.5	0.0		22300	1

LAMINATE PHYSICAL PROPERTIES									
Material: T300/AFR800									
Lam. No.	Fiber Orient.	No. Plies	Spec. Grav.	Resin Content (% by wt)	Fiber Content (% by vol)	Void Content (% by vol)	Thick. per ply (10^{-3} in.)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
F28	$\pm 45^{\circ}$	8	1.59	31.7	63.8	4.4		22300	1
F29	$\pm 45^{\circ}$	8	1.55	33.1	61.1	0.0		22300	1
F30	$\pm 45^{\circ}$	8	1.58	31.4	63.7	0.0		22300	1
F31	$\pm 45^{\circ}$	8	1.58	25.9	68.9	0.0		22300	1
F32	$\pm 45^{\circ}$	8	1.60	26.4	69.3	0.0		22300	1
F33	$\pm 45^{\circ}$	8	1.61	26.3	69.8	0.0		22300	1
F34	90°	15	1.60	26.0	70.4	0.0		22300	1
F35	90°	20	1.60	25.1	70.5	0.0		22300	1
F36	0°	20	1.61	24.4	71.6	0.0		22300	1
F37	0°	50	1.59	25.8	69.4	0.0		22300	1
F38	$\pm 45^{\circ}$	50	1.59	27.6	67.2	0.0		22300	1
Avg.			1.60	26.6	69.1	0.2			
Std. Dev.			± 0.04	± 2.8	3.7	± 0.8			

LAMINATE PHYSICAL PROPERTIES									
Material: SiC/5506									
Lam. No.	Fiber Orient.	No. Plies	Spec. Grav.	Resin Content (% by wt)	Fiber Content (% by vol)	Void Content (% by vol)	Thick. per ply (10^{-3} in.)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
G9	90°	15	2.37	19.2	59.5	0		2	1
G10	0°	40	2.36	17.9	59.5	1.70		2	1
G14	$\pm45^\circ$	8	2.33	19.4	57.5	1.52		2B	2
G15	$\pm45^\circ$	8	2.34	19.1	58.1	1.27		2B	2
G16	$\pm45^\circ$	8	2.30	22.0	53.9	0		2B	2
G17	$\pm45^\circ$	8	2.35	20.3	57.5	0		2B	2
G20	0°	14	2.34	20.6	57.3	0		2B	2
G21	90°	14	2.40	18.2	60.4	0.02		2B	2
G22	90°	15	2.37	19.6	58.6	0		2B	2
G23	0°	6	2.39	18.4	60.0	0		2B	2
G24	90°	15	2.38	20.3	58.3	0		2B	2
G25	90°	15	2.38	18.8	59.4	0		2B	2
G26	90°	15	2.38	17.5	60.4	1.87		2B	2
G27	$\pm45^\circ$	8	2.36	19.4	58.4	0.12		2A	2A
G28	$\pm45^\circ$	8	2.34	19.1	58.1	1.41		2A	2A
G29	$\pm45^\circ$	8	2.34	19.5	57.9	0.66		2A	2A
G30	$\pm45^\circ$	8	2.33	19.3	57.6	1.41		2A	2A
G31	$\pm45^\circ$	8	2.32	19.0	57.7	2.24		2A	2A
G32	(1)	20	2.35	19.4	58.3	1.01		2A	2A
G33	(1)	20	2.36	18.6	59.0	1.17		2A	2A
G34	(1)	20	2.35	19.0	58.6	0.85		2A	2A
G35	(1)	20	2.35	18.7	58.4	1.26		2A	2A
G36	(1)	20	2.36	18.8	58.7	0.89		2A	2A
G37	0°	14	2.41	17.4	61.2	0.46		2A	2A
G38	0°	15	2.39	18.3	60.1	0		2A	2A
G39	(1)	20	2.35	18.7	58.8	1.19		2A	2A
G40	(1)	20	2.35	19.4	58.2	0.36		2A	4

(1) $(0,45,-45,0,0,-45,45,0,90,0)_s$-20 ply.

LAMINATE PHYSICAL PROPERTIES									
Material: SiC/5506									
Lam. No.	Fiber Orient.	No. Plies	Spec. Grav.	Resin Content (% by wt)	Fiber Content (% by vol)	Void Content (% by vol)	Thick. per ply (10^{-3} in.)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
G41	(1)	20	2.36	18.6	59.0	1.02		2A	4
G42	90°	16	2.38	18.5	60.0	0.11		2A	4
G43	(1)	20	2.36	18.6	58.9	1.15		2A	4
G44	(1)	20	2.36	18.9	58.8	0.64		2A	4
Avg.			2.36	19.0	58.6	0.7			
Std. Dev.			0.02	0.9	1.3	0.7			

(1) $(0,45,-45,0,0,-45,45,0,90,0)_S$-20 ply.

LAMINATE PHYSICAL PROPERTIES									
Material: HyE 2034D									
Lam. No.	Fiber Orient.	No. Plies	Spec. Grav.	Resin Content (% by wt)	Fiber Content (% by vol)	Void Content (% by vol)	Thick. per ply (10^{-3} in.)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
H1	0°	6	1.82	23.0	70.1	0.00		C0-010	1
H2	0°	6	1.81	23.0	69.8	0.00			
H3	90°	15	1.81	23.3	69.4	0.00			
H4	90°	15	1.80	23.5	69.0	0.00			
H6	90°	15	1.81	23.7	69.1	0.00			
H7	90°	15	1.78	26.3	65.6	0.00			
H8	0°	14	1.82	23.4	69.8	0.00			
H9	90°	14	1.79	24.4	67.7	0.00			
H10	±45°	8	1.81	24.9	68.0	0.00			
H11			1.80	25.1	67.5	0.00			
H12			1.82	25.1	68.2	0.00			
H13			1.80	25.4	67.1	0.00			
H14			1.79	24.9	67.3	0.00			
H15			1.80	23.2	69.1	0.00			
H16			1.80	26.1	66.5	0.00			
H17			1.80	25.9	66.8	0.00			
H18			1.82	24.6	68.6	0.00			
H19			1.81	23.2	69.5	0.00			
H20	(1)	20	1.81	23.7	68.9	0.00			
H21			1.81	23.9	68.9	0.00			
H22			1.81	24.9	67.6	0.00			
H23			1.81	24.2	68.6	0.00			
H24			1.80	25.1	67.6	0.00			
H25			1.80	24.1	68.4	0.00			
H26			1.79	24.4	67.6	0.00			
H27			1.80	25.1	62.9	0.00			

(1) $(0,45,-45,0,0,-45,45,0,90,0)_s$ - 20 ply.

LAMINATE PHYSICAL PROPERTIES									
Material: HyE 2034D									
Lam. No.	Fiber Orient.	No. Plies	Spec. Grav.	Resin Content (% by wt)	Fiber Content (% by vol)	Void Content (% by vol)	Thick. per ply (10^{-3} in.)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
H28	(1)	20	1.80	24.8	68.4	0.00		CO-010	1
H29	90°	20	1.81	23.9	68.8	0.00			
H30	0°	20	1.81	23.4	69.4	0.00			
H31	0°	15	1.81	25.0	68.1	0.00			
H32	0°	40	1.79	25.9	66.4	0.00			
H33	±45°	40	1.81	23.9	68.7	0.00			
H34	±45°	40	1.78	27.0	65.1	0.00			
H35	90°	15	1.80	25.1	68.8	0.00			
H36	90°	15	1.80	24.5	67.9	0.00			
Avg.			1.80	24.5	68.0	0			
Std.Dev.			0.01	1.0	1.5				

(1) $(0,45,-45,0,0,-45,45,0,90,0)_s$ - 20 ply.

LAMINATE PHYSICAL PROPERTIES									
Material: T300/V378A									
Lam. No.	Fiber Orient.	No. Plies	Spec. Grav.	Resin Content (% by wt)	Fiber Content (% by vol)	Void Content (% by vol)	Thick. per ply (10^{-3}in.)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
I-1	90°	14	1.56	23.5	68.1	3.17		2W4683	1
I-2	90°	14	1.59	22.0	70.7	1.53		2W4683	1
I-3	90°	8	1.58	23.7	68.9	1.92		2W4683	1
I-4	±45°	8	1.59	29.8	63.7	0.86		2W4683	1
I-5	±45°	8	1.61	24.6	69.4	-0.54		2W4683	1
I-6	±45°	8	1.58	26.8	66.1	0.58		2W4683	1
I-7	±45°	8	1.61	27.9	66.3	-1.70		2W4683	1
I-8	±45°	8	1.56	26.6	65.4	1.88		2W4683	1
I-9	±45°	8	1.59	28.3	65.1	-0.58		2W4683	1
I-10	±45°	8	1.61	27.4	66.8	-1.52		2W4683	1
I-11	±45°	8	1.56	27.3	64.8	1.66		2W4683	1
I-12	0/45/90	20	1.57	29.0	63.7	0.46		2W4683	1
I-13	0/45/90	20	1.57	25.2	67.1	1.75		2W4683	1
I-14	0/45/90	20	1.57	25.4	66.9	1.67		2W4683	1
I-15	90°	15	1.59	25.5	67.7	0.39		2W4683	1
I-17	0°	6	1.58	23.4	68.2	1.73		2W4683	1
I-18	90°	15	1.58	22.6	69.9	1.99		2W4683	1
I-19	90°	15	1.59	28.2	65.2	-0.54		2W4683	1
I-20	90°	15	1.57	25.7	66.7	1.58		2W4683	1
I-21	90°	15	1.57	27.9	64.7	0.83		2W4683	1
I-22	±45°	8	1.58	24.1	68.6	1.50		2W4683	1
I-35	0/90/45	20	1.58	26.6	66.3	0.65		2W4810	1
I-36	0/90/45	20	1.58	24.0	68.7	1.54		2W4810	1
I-37	0/90/45	20	1.58	26.0	66.8	0.84		2W4810	1
I-38	0/90/45	20	1.60	24.4	69.2	0.15		2W4810	1
I-39	0/90/45	20	1.59	24.9	68.3	0.63		2W4810	1

LAMINATE PHYSICAL PROPERTIES

Material: T300/V378A

Lam. No.	Fiber Orient.	No. Plies	Spec. Grav.	Resin Content (% by wt)	Fiber Content (% by vol)	Void Content (% by vol)	Thick. per ply (10^{-3}in.)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
I-40	0/90/45	20	1.61	23.4	70.5	-0.12		2W4810	1
I-41	0°	20	1.59	21.7	71.1	1.68		2W4810	1
I-42	90°	20	1.60	26.6	67.1	-0.63		2W4810	1
I-43	0°	40	1.57	25.0	67.3	1.80		2W4810	1
I-44	±45°	40	1.57	24.0	68.2	2.15		2W4810	1
Avg.			1.58	25.6	67.0	1.44			
S.D.			0.02	2.2	2.2	1.19			

LAMINATE PHYS[illegible]AL PROPERTIES

Material: HyE 1076J

Lam. No.	Fiber Orient.	No. Plies	Spec. Grav.	Resin Content (% by wt)	Fiber Content (% by vol)	Void Content (% by vol)	Thick. per ply (10^{-3} in.)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
J1	90°	14	1.62	26.3	67.1	-0.37		C1-285	1
J2	0°	14	1.61	23.8	68.9	1.13		C1-285	1
J3	±45°	8	1.62	26.2	67.1	-0.34		C1-285	1
J4	±45°	8	1.62	24.6	68.7	0.26		C1-285	1
J5	±45°	8	1.62	24.3	68.9	0.34		C1-285	1
J6	±45°	8	1.62	26.1	67.3	-0.28		C1-285	1
J7	±45°	8	1.61	24.7	68.5	0.40		C1-285	1
J8	±45°	8	1.62	25.2	68.1	0.05		C1-285	1
J9	±45°	8	1.62	26.2	67.2	-0.05		C1-285	1
J10	±45°	8	1.61	24.9	67.9	0.95		C1-285	1
J11	±45°	8	1.61	25.6	67.3	0.33		C1-285	1
J12	±45°	8	1.62	25.7	67.2	0.16		C1-285	1
J13	(1)	20	1.65	25.5	69.0	-1.75		C1-285	1
J14	(1)	20	1.61	25.1	67.7	0.69		C1-285	1
J15	(1)	20	1.62	25.6	67.7	-0.12		C1-285	1
J16	(1)	20	1.63	25.0	68.8	-0.73		C1-285	1
J17	(1)	20	1.62	24.8	68.5	0.18		C1-285	1
J18	0°	6	1.64	32.9	61.9	-3.95		C1-285	1
J19	0°	6	1.58	37.7	55.3	-1.85		C1-285	1
J20	(1)	20	1.62	24.1	69.1	0.42		C1-285	1
J21	(1)	20	1.60	25.4	67.0	1.18		C1-285	1
J22	(1)	20	1.62	24.6	68.6	0.23		C1-285	1
J23	(1)	20	1.62	24.4	68.9	0.10		C1-285	1
J24	(1)	20	1.62	24.8	68.5	0.17		C1-285	1
J25	(1)	20	1.63	24.9	68.8	-0.47		C1-285	1
J26	90°	15	1.63	24.0	69.7	-0.37		C1-285	1
J27	90°	15	1.64	24.2	69.9	-0.83		C1-285	1

(1) $(0,45,-45,0,0,-45,45,0,90,0)_s$ - 20 ply.

LAMINATE PHYSICAL PROPERTIES									
Material: HyE 1076J									
Lam. No.	Fiber Orient.	No. Plies	Spec. Grav.	Resin Content (% by wt)	Fiber Content (% by vol)	Void Content (% by vol)	Thick. per ply (10^{-3} in.)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
J28	90°	15	1.64	25.0	69.1	-1.14		C1-285	1
J29	90°	15	1.63	24.9	68.8	-0.47		C1-285	1
J30	90°	15	1.64	24.4	69.6	-0.70		C1-285	1
J31	90°	20	1.63	24.5	69.3	-0.55		C1-285	1
J32	0°	20	1.63	24.0	69.7	-0.38		C1-285	1
J33	±45°	40	1.62	26.3	66.9	-0.17		C1-285	1
J34	±45°	40	1.62	24.8	68.4	0.17		C1-285	1
Avg.			1.62	25.6	68.0	≑0[1]			
S.D.			0.01	2.6	1.5				

[1]Negative void contents can be computed if the assumed resin and fiber specific gravities are not precisely accurate, or if the measured composite specific gravity or resin content is not exact. In any case, they reflect a low void content and are assumed here to represent a void free, or zero void content condition.

LAMINATE PHYSICAL PROPERTIES									
Material: G-160/6535-1									
Lam. No.	Fiber Orient.	No. Plies	Spec. Grav.	Resin Content (% by wt)	Fiber Content (% by vol)	Void Content (% by vol)	Thick. per ply (10^{-3}in.)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
K3	±45°	8	1.60	25.7	68.0	0.28			440
K4	±45°	8	1.60	26.6	67.1	-0.89			
K5	±45°	8	1.60	25.8	67.9	-0.60			
K6	±45°	8	1.61	26.1	68.0	-1.32			
K7	±45°	8	1.61	26.8	67.2	-1.36			
K8	±45°	8	1.60	25.6	67.9	-0.32			
K9	±45°	8	1.61	26.5	67.6	-1.48			
K10	±45°	8	1.61	26.3	67.6	-1.21			
K11	±45°	8	1.60	25.5	68.3	-0.70			
K12	0°	6	1.62	26.0	68.3	-2.13			
K13	0°	6	1.63	23.6	71.3	-1.92			
K14	90°	15	1.61	25.9	68.3	-1.47			
K15	90°	15	1.61	25.6	68.6	-1.37			
K16	90°	15	1.61	25.9	68.3	-1.49			
K17	90°	15	1.62	25.4	69.0	-1.49			
K18	90°	15	1.59	27.3	66.1	-0.19			
K19	90°	21	1.62	22.9	71.5	-1.00			
K20	0°	40	1.61	24.4	69.6	-0.72			
K21	0°	21	1.62	23.4	70.5	-0.37			
K24	(1)	20	1.61	26.3	67.8	-1.42			
K25	(1)	20	1.61	26.1	68.0	-1.33			
K26	(1)	20	1.61	25.3	68.7	-1.07			
K34	(2)	16	1.62	26.4	68.2	-2.06			441
K35	(2)	16	1.60	26.2	67.6	-0.95			
K36	(2)	16	1.61	26.9	67.3	-1.63			
K37	(3)	20	1.60	26.7	67.1	-0.70			
K38	(3)	20	1.60	26.6	67.3	-1.70			

(1) $(0,45,-45,0,0,-45,45,0,90,0)_S$-20 ply
(2) $(0,45,-45,0,0,-45,45,0)_S$-16 ply
(3) $(0,90,45,-45,0,0,-45,45,0,0)_S$-20 ply

LAMINATE PHYSICAL PROPERTIES									
Material: G-160/6535-1									
Lam. No.	Fiber Orient.	No. Plies	Spec. Grav.	Resin Content (% by wt)	Fiber Content (% by vol)	Void Content (% by vol)	Thick. per ply (10^{-3} in.)	Prepreg Lot/ Batch No.	Prepreg Spool/Roll No.
K39	(3)	20	1.61	25.9	68.3	-1.49			441
K40	±45°	40	1.61	25.7	68.3	-0.97			
K41	0°	14	1.62	23.9	70.6	-1.39			
K42	90°	14	1.61	25.6	68.6	-1.36			
K43	90°	14	1.61	24.9	68.9	-0.68			
K44	90°	21	1.60	25.4	68.1	-0.24			
K45	90°	15	1.61	25.7	68.4	-1.19			
Avg.			1.61	25.7	68.4	≐ 0[1]			
Std.Dev.			0.01	1.0	1.2				

[1] Negative void contents can be computed if the assumed resin and fiber specific gravities are not precisely accurate, or if the measured composite specific gravity or resin content is not exact. In any case, they reflect a low void content and are assumed here to represent a void free, or zero void content condition.

APPENDIX D
TENSION DATA

All of the tension data generated during this program are listed in this section. These data are summarized and presented in both tabular and graphical form in Sections 4.1 through 4.6.

The specimen numbering notation used in this and subsequent appendices is illustrated in the example below.

F 23-5

Indicates the material — F

23 — panel number from which specimen was machined

5 — specimen number from the panel

F - T300/AFR800

G - SiC/5506

H - HyE 2034D

I - T300/V378A

J - HyE 1076J

K - G-160/6535-1

Test: Tension Material: T300/AFR800

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μ in/in)	Remarks
F1-4	0°	-67	178.6	20.37	178.6	0.32	8,400	
F3-7	0°	-67	178.9	20.38	178.9	0.33	8,200	
F4-2	0°	-67	212.1	21.46	212.1	0.32	9,400	
F4-16	0°	-67	191.5	20.95	191.5	0.33	8,700	
F5-12	0°	-67	172.2	21.21	172.2	0.30	7,900	
Avg.			186.7	20.87	186.7	0.32	8,520	
Std.Dev.			15.8	0.49	15.8	0.01	570	
F1-3	0°	72	186.0	18.85	186.0	0.31	9,000	
F3-1	0°	72	169.6	19.15	169.6	0.33	8,400	
F3-13	0°	72	161.6	18.39	161.6	0.27	8,200	
F4-8	0°	72	205.6	17.22	205.6	0.29	9,700	
F5-5	0°	72	175.1	19.86	175.1	0.35	8,200	
Avg.			179.6	18.69	179.6	0.31	8,700	
Std.Dev.			17.0	0.98	17.0	0.03	650	
F1-11	0°	260	174.3	20.14	174.3	0.29	8,400	
F3-3	0°	260	176.7	19.82	176.7	0.30	8,400	
F4-3	0°	260	204.0	20.40	204.0	0.28	9,400	
F5-7	0°	260	213.3	20.88	213.3	0.32	9,800	
F5-13	0°	260	201.2	20.76	201.2	0.34	9,200	
Avg.			193.9	20.40	193.9	0.31	9,040	
Std.Dev.			17.4	0.44	17.4	0.02	620	
F1-6	0°	350	185.8	19.51	185.8	0.37	9,200	
F1-16	0°	350	159.7	19.88	159.7	0.32	7,700	
F3-11	0°	350	147.5	19.39	147.5	0.40	7,500	
F4-7	0°	350	173.8	20.37	173.8	---	8,100	
F5-3	0°	350	200.9	20.22	200.9	0.33	9,400	
Avg.			173.5	19.87	173.5	0.36	8,380	
Std.Dev.			21.0	0.43	21.0	0.04	870	

Test: Tension   Material: AFR-800

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6 psi)	Stress at Prop. Lim. (ksi)	Pois. Ratio	Ultimate Strain (μ in/in)	Remarks
F7-8	90°	-67	4.55	1.56	4.55	---	2,940	
F8-8	90°	-67	4.58	1.63	1.60	---	2,875	
F9-10	90°	-67	5.19	1.58	5.19	---	3,015	
F11-5	90°	-67	2.80	1.70	1.20	---	1,695	
F12-2	90°	-67	6.31	1.70	1.93	---	3,825	
Avg.			4.69	1.63	2.89	---	2,870	
Std.Dev.			1.27	0.07	1.84	---	760	
F7-9	90°	72	4.90	1.47	4.90	---	3,325	
F8-9	90°	72	5.75	1.47	4.58	---	3,950	
F11-1	90°	72	5.14	1.49	4.26	---	3,450	
F12-5	90°	72	3.20	1.55	3.20	---	2,075	
F13-7	90°	72	3.93	1.44	3.93	---	2,750	
Avg.			4.58	1.48	4.17	---	3,110	
Std.Dev.			1.01	0.04	0.65	---	720	
F8-5	90°	260	5.56	1.38	5.56	---	4,050	
F9-9	90°	260	4.40	1.31	4.20	---	3,500	
F11-2	90°	260	4.33	1.39	2.46	---	3,200	
F12-8	90°	260	4.53	1.33	2.93	---	3,500	
F12-10	90°	260	4.59	1.41	3.78	---	3,290	
Avg.			4.68	1.36	3.79	---	3,510	
Std.Dev.			0.50	0.04	1.21	---	330	
F7-1	90°	350	5.19	1.20	2.08	---	4,550	
F8-3	90°	350	5.08	1.26	1.59	---	4,275	
F9-1	90°	350	4.80	1.12	3.72	---	4,350	
F12-7	90°	350	5.51	1.26	2.49	---	4,925	
F13-5	90°	350	6.53	1.09	4.40	---	6,450	
Avg.			5.42	1.19	2.86	---	4,910	
Std.Dev.			0.67	0.08	1.17	---	900	

Test: Tension				Material: AFR-800				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μ in/in)	Remarks
F23-5	±45°	-67	27.81	2.37	11.57	0.68	9,600+	
F24-1	±45°	-67	26.73	2.31	9.58	0.72	10,600+	
F25-7	±45°	-67	25.69	2.22	11.57	0.71	14,800	
F26-4	±45°	-67	25.24	2.10	6.09	0.62	16,000	
F27-10	±45°	-67	26.74	2.39	8.04	0.73	9,400+	
Avg.			26.44	2.28	9.37	0.69	12,080	
Std.Dev.			1.00	0.12	2.36	0.04	3,090	
F23-9	±45°	72	24.07	2.31	4.05	0.73	20,000	
F24-9	±45°	72	23.80	2.45	6.45	0.72	16,600	
F25-5	±45°	72	21.50	2.09	3.41	0.74	18,350	
F26-10	±45°	72	23.70	2.40	4.67	0.82	17,400	
F27-1	±45°	72	23.14	2.50	4.87	0.74	15,800	
Avg.			23.24	2.35	4.69	0.75	17,630	
Std.Dev.			1.03	0.16	1.14	0.04	1,630	
F23-11	±45°	260	18.0	2.26	5.53	0.78	23,100+	
F24-4	±45°	260	15.4	2.08	4.55	0.78	11,000	
F25-1	±45°	260	17.2	2.24	4.56	0.78	22,000	
F26-8	±45°	260	17.5	2.10	5.22	0.80	32,000	
F27-3	±45°	260	15.8	2.01	5.01	0.77	12,800+	
Avg.			16.8	2.14	4.93	0.78	21,580+	
Std.Dev.			1.12	0.11	0.36	0.01	7,090+	
F23-3	±45°	350	17.06	1.61	2.05	0.86	46,800+	
F24-7	±45°	350	16.37	1.73	2.67	0.94	38,800+	
F25-10	±45°	350	17.13	1.71	1.78	0.92	34,000+	
F26-2	±45°	350	15.34	1.52	1.96	0.90	37,900+	
F27-5	±45°	350	15.43	1.45	2.17	0.79	39,750+	
Avg.			16.27	1.62	2.13	0.88	39,450	
Std.Dev.			0.86	0.12	0.34	0.06	4,650	

Test: Tension   Material: SIC/5506

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6 psi)	Stress at Prop. Lim. (ksi)	Pois. Ratio	Ultimate Strain (μ in/in)	Remarks
G23-2	0°	-67	204.9	33.43	160.5	0.24	7,500	
G23-5	0°	-67	198.8	31.53	101.8	0.24	7,400	
G23-12	0°	-67	235.4	31.40	157.5	0.18	7,600	
G23-14	0°	-67	233.1	33.50	80.4	0.22	7,900	
G23-17	0°	-67	235.8	31.53	147.4	0.24	7,600	
Avg.			221.6	32.28	129.5	0.22	7,600	
Std.Dev.			18.2	1.09	36.2	0.03	190	
G23-1	0°	72	232.1	32.05	92.6	---	8,100	
G23-6	0°	72	241.7	33.50	83.1	0.20	8,800	
G23-11	0°	72	220.3	33.09	58.2	0.24	7,100	
G23-16	0°	72	222.9	32.75	80.6	0.23	7,100	
G23-19	0°	72	228.5	35.59	42.7	0.24	7,200	
Avg.			229.1	33.40	71.4	0.23	7,660	
Std.Dev.			8.4	1.34	20.4	0.02	760	
G23-3	0°	260	188.1	33.50	85.8	0.30	6,300	failed @ tab
G23-9	0°	260	205.0	32.76	99.6	0.24	7,300	failed @ tab
G23-10	0°	260	178.8	33.36	74.7	0.20	5,200+	failed @ tab
Avg.			190.6	33.21	86.7	0.25	6,800	*
Std.Dev.			13.3	0.39	12.5	0.05	---	
G23-13	0°	350	181.0	35.80	34.9	0.23	5,400+	
G23-15	0°	350	161.7	31.59	69.8	0.23	4,600	failed @ tab
G23-18	0°	350	180.7	31.72	67.4	0.49	5,400+	
Avg.			174.5	33.04	57.4	0.32	5,130+	
Std.Dev.			11.0	2.39	19.5	0.15	460	

*Excludes G23-10 on which strain gage malfunctioned before end of test

Test: Tension Material: SIC/5506

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μ in/in)	Remarks
G9-7	90°	-67	10.27	3.96	5.38	---	2,880	
G22-2	90°	-67	10.44	3.66	7.90	---	2,920	
G24-3	90°	-67	8.33	3.90	6.57	---	2,250	
G25-4	90°	-67	11.55	3.93	4.74	---	3,380	
G26-5	90°	-67	8.31	3.88	6.26	---	2,310	
Avg.			9.78	3.86	6.17	---	2,750	
Std.Dev.			1.42	0.12	1.21	---	470	
G9-3	90°	72	8.99	2.96	4.98	---	3,400	
G22-1	90°	72	10.43	3.13	4.82	---	3,910	
G24-2	90°	72	9.78	3.07	3.61	---	3,740	
G25-3	90°	72	9.62	2.89	3.92	---	3,760	
G26-4	90°	72	9.72	2.90	3.86	---	3,830	
Avg.			9.71	2.99	4.24	---	3,730	
Std.Dev.			0.51	0.10	0.62	---	190	
G9-4	90°	260	6.34	2.09	2.78	---	4,760	
G22-3	90°	260	6.56	1.88	2.76	---	4,990	
G24-1	90°	260	6.38	2.17	2.64	---	4,090	
G25-6	90°	260	6.55	1.97	3.10	---	4,640	
G26-1	90°	260	6.39	1.77	2.91	---	5,000	
Avg.			6.44	1.97	2.84	---	4,700	
Std.Dev.			0.104	0.16	0.18	---	370	
G9-9	90°	350	3.84	0.91	1.62	---	6,000	
G22-5	90°	350	4.39	1.10	1.65	---	7,500	
G24-4	90°	350	4.92	1.19	1.96	---	8,250	
G25-5	90°	350	4.40	1.13	1.76	---	8,500	
G-26-2	90°	350	4.14	0.89	1.76	---	7,500	
Avg.			4.34	1.04	1.75	---	7,550	
Std.Dev.			0.40	0.13	0.13	---	980	

Test: Tension   Material: SIC/5506

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μ in/in)	Remarks
G14-3	±45°	-67	20.63	3.93	5.70	0.66	9,350	
G14-4	±45°	-67	20.24	3.93	6.48	0.73	9,800	
G15-2	±45°	-67	20.41	3.50	5.97	0.59	N.A.	Gage failed during test
G17-3	±45°	-67	17.69	3.50	5.96	0.59	7,050	
G17-6	±45°	-67	19.66	3.67	7.13	0.72	8,200	
Avg.			19.72	3.71	6.25	0.66	8,600	
Std.Dev.			1.19	0.22	0.57	0.07	123	
G14-5	±45°	72	17.69	2.65	6.76	0.69	15,950	
G15-1	±45°	72	16.52	2.96	4.80	0.66	14,700	
G15-4	±45°	72	17.52	3.08	4.81	0.80	15,900	
G17-1	±45°	72	17.95	3.40	4.90	0.71	15,200	
G17-4	±45°	72	16.92	2.75	4.42	0.86	15,800	
Avg.			17.32	2.97	5.14	0.74	15,510	
Std.Dev.			0.58	0.30	0.92	0.08	540	
G14-7	±45°	260	11.57	1.96	1.86	0.93	42,000+	Strain exceeded gage limit
G16-4	±45°	260	12.45	1.35	1.32	0.95	40,500+	
G17-2	±45°	260	12.25	1.86	2.04	0.78	34,500+	
G17-7	±45°	260	10.66	1.57	1.13	1.02	23,500+	
G17-8	±45°	260	10.69	1.40	1.57	0.76	35,000+	
Avg.			11.52	1.63	1.59	0.89	35,100+	
Std.Dev.			0.84	0.27	0.37	0.11	7,270	
G14-1	±45°	350	7.98	0.77	1.44	0.57	35,000+	Strain exceeded gage limit
G14-2	±45°	350	7.90	0.39	0.88	0.75	35,000+	
G14-6	±45°	350	7.90	0.65	0.98	0.71	20,000+	
G15-3	±45°	350	8.17	0.39	0.66	0.83	29,500+	
G17-5	±45°	350	7.67	0.36	0.67	0.83	35,000+	
Avg.			7.93	0.51	0.93	0.74	30,900+	
Std.Dev.			0.18	0.19	0.32	0.11	6,540	

Test: Tension				Material: SIC/5506				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
G33-7	0/±45/90	72	125.6	21.33	19.6	N.A.	5,800	
G36-6	0/±45/90	72	N.A.	23.67	21.8	0.18	N.A.	Failed at tab end
G39-7	0/±45/90	72	105.9	19.42	39.3	0.41	5,575	
G41-5	0/±45/90	72	118.0	18.92	47.4	0.37	5,775	Failed at tab end
G44-6	0/±45/90	72	125.2	19.38	65.0	0.28	5,750	
Avg.			108.6	20.54	38.6	0.31	5,725	
Std.Dev.			24.9	1.97	18.8	0.10	100	
G33-2	0/±45/90	260	111.7	19.0	35.1	0.52	5,650+	*
G34-9	0/±45/90	260	118.6	19.0	36.6	0.61	5,750+	*
G39-3	0/±45/90	260	126.2	19.1	66.5	0.34	5,900	
G39-4	0/±45/90	260	107.4	19.6	43.6	0.40	5,650	
G41-9	0/±45/90	260	122.3	18.4	63.6	0.39	5,750	
Avg.			117.2	19.0	49.1	0.45	5,740	
Std.Dev.			7.7	0.4	15.0	0.11	100	
G34-3	0/±45/90	350	107.0	18.7	50.1	0.46	5,700	
G40-2	0/±45/90	350	115.6	17.8	62.6	0.46	4,425	*
G41-6	0/±45/90	350	102.1	17.3	53.5	0.33	5,800	
G44-5	0/±45/90	350	103.9	18.4	74.9	0.37	4,850	
Avg.			107.2	18.1	60.3	0.40	5,190	
Std.Dev.			6.0	0.6	11.1	0.06	670	
G32-8	0/±45/90	72	105.8					Based on net cross-
G35-2	0/±45/90	72	97.6					sectional area. Specimens
G40-4	0/±45/90	72	104.2					had a 0.1935 inch dia-
G44-1	0/±45/90	72	100.2					meter hole in center of
G44-3	0/±45/90	72	104.7					gage section.
Avg.			102.5					
Std.Dev.			3.5					

*Tabs debonded, retabbed and tested for strength only, elastic data taken from first test

Test: Tension				Material: HyE 2034D				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
H1-3	0°	-67	149.6	51.12	149.6	---	2700	gage failed
H1-10	0°	-67	108.9	50.61	108.9	0.36	---	tabs debonded
H2-4	0°	-67	105.3	72.46	105.3	---	1500	gage failed
H2-13	0°	-67	90.7	45.41	90.7	0.25	1900	
H1-17	0°	-67	157.0	60.00	157.0	0.29	2500	
Avg.			122.3	55.92	122.3	0.30	2150	
Std.Dev.			29.2	10.63	29.2	0.06	550	
H1-9	0°	72	151.6	41.75	151.6	0.03	2800	
H1-13	0°	72	80.3	47.81	80.3	0.10	2000	
H1-16	0°	72	72.1	47.71	72.1	0.45	1400	
H2-6	0°	72	130.7	41.67	130.7	0.18	2500	
H2-15	0°	72	97.5	43.54	97.5	0.35	1700	
Avg.			106.5	44.50	106.5	0.22	2080	
Std.Dev.			33.8	3.07	33.8	0.17	570	
H1-1	0°	260	96.5	44.90	96.5	0.24	1960	gage failed
H1-12	0°	260	167.3	47.81	167.3	0.47	3100	
H1-15	0°	260	120.2	47.99	120.2	0.27	2700	
H2-5	0°	260	137.4	53.76	137.4	0.34	2500	
H2-10	0°	260	146.0	47.62	146.0	0.27	2800	
Avg.			133.5	48.42	133.5	0.32	2780	excludes H1-1
Std.Dev.			26.7	3.25	26.7	0.09	250	
H1-2	0°	350	145.5	46.39	145.5	0.25	2800	
H1-7	0°	350	140.3	47.71	140.3	0.40	2800	
H2-1	0°	350	130.0	46.30	130.0	0.30	2700	
H2-9	0°	350	165.0	55.44	165.0	0.29	3200	
H2-11	0°	350	94.3	47.62	94.3	0.27	1800	
Avg.			135.0	48.69	135.0	0.30	2660	
Std.Dev.			26.1	3.83	26.1	0.06	520	

Test: Tension — Material: HyE 2034D

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
H3-3	90°	-67	2.34	0.86	2.34	---	2400	
H3-7	90°	-67	2.68	1.06	2.68	---	2600	
H6-6	90°	-67	1.56	0.99	1.56	---	1800	
H7-5	90°	-67	1.72	0.87	1.72	---	1700	
H7-10	90°	-67	2.64	0.82	2.64	---	2800	
Avg.			2.19	0.92	2.19	---	2260	
Std.Dev.			0.52	0.10	0.52	---	490	
H3-1	90°	72	1.81	0.84	1.81	---	2100	
H4-5	90°	72	2.29	0.88	2.29	---	2500	
H7-3	90°	72	1.86	0.86	1.86	---	2100	
H6-7	90°	72	2.34	0.84	2.34	---	2800	
H4-9	90°	72	2.06	0.92	2.06	---	2300	
Avg.			2.07	0.87	2.07	---	2360	
Std.Dev.			0.24	0.03	0.24	---	300	
H3-6	90°	260	1.46	0.79	1.46	---	1900	
H4-4	90°	260	2.21	0.77	2.21	---	2900	
H7-2	90°	260	1.24	0.79	1.24	---	1600	
H7-8	90°	260	1.94	0.79	1.94	---	2500	
H7-9	90°	260	1.80	0.81	1.80	---	2200	
Avg.			1.73	0.79	1.73	---	2220	
Std.Dev.			0.38	0.01	0.38	---	510	
H4-2	90°	350	1.92	0.91	1.10	---	2300	
H4-10	90°	350	0.87	1.12	0.81	---	1000	
H6-3	90°	350	1.24	0.91	0.68	---	1600	
H6-9	90°	350	1.20	0.93	0.77	---	1500	
H7-7	90°	350	1.75	0.90	1.15	---	2300	
Avg.			1.40	0.96	0.90	---	1740	
Std.Dev.			0.43	0.10	0.21	---	560	

Test: Tension				Material: HyE 2034D				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
H11-8	±45°	-67	11.67	3.40	4.17	0.77	5000	
H16-4	±45°	-67	12.24	3.50	3.92	0.71	4400	
H17-4	±45°	-67	11.62	3.50	4.65	0.73	4000	
H17-7	±45°	-67	12.45	3.43	4.69	0.71	5000	
H12-7	±45°	-67	11.34	3.70	3.90	0.80	4100	
Avg.			11.86	3.50	4.26	0.74	4500	
Std.Dev.			0.46	0.11	0.38	0.04	480	
H11-7	±45°	72	11.02	2.84	4.03	0.91	5600	
H13-8	±45°	72	11.00	2.73	4.87	0.61	5100	
H15-4	±45°	72	10.78	2.71	4.51	1.00	6800	
H15-5	±45°	72	11.18	2.78	4.75	0.89	5500	
H15-7	±45°	72	10.29	2.65	4.76	0.89	5900	
Avg.			10.85	2.74	4.58	0.87	5780	
Std.Dev.			0.35	0.07	0.34	0.12	640	
H10-2	±45°	260	9.35	2.44	3.05	0.75	6560	
H12-3	±45°	260	9.39	2.51	3.38	0.75	5380	
H13-1	±45°	260	9.75	2.50	2.50	0.88	8900	
H14-10	±45°	260	8.95	2.38	3.33	0.88	5660	
H17-6	±45°	260	9.49	1.32	5.24	1.00	5460	
Avg.			9.39	2.23	3.50	0.85	6390	
Std.Dev.			0.29	0.51	1.03	0.11	1480	
H10-5	±45°	350	8.72	2.56	2.82	0.80	7100	
H11-9	±45°	350	8.42	2.22	2.44	1.06	7100	
H14-5	±45°	350	9.08	2.02	2.90	0.83	9280	
H18-2	±45°	350	9.13	2.79	3.51	1.04	7100	
H19-4	±45°	350	8.44	2.45	3.06	1.10	7800	
Avg.			8.76	2.41	2.95	0.96	7680	
Std.Dev.			0.34	0.30	0.39	0.14	950	

Test: Tension				Material: HyE 2034D				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
H20-10	0/±45/90°	72	81.21	29.67	62.31	*	2700	*All 90° strain measure-
H21-5	0/±45/90°	72	80.80	30.77	80.80	*	2600	ments incorrect due to
H22-4	0/±45/90°	72	68.37	27.61	61.06	*	2450	recorder error--avg.
H25-2	0/±45/90°	72	83.03	27.44	65.85	*	3280	value from extra
H33-10	0/±45/90°	72	65.70	26.58	65.70	*	2600	specimen tested later.
Avg.			75.82	28.41	67.14	0.42	2730	
Std.Dev.			8.12	1.74	7.92		320	
H21-8	0/±45/90°	260	82.73	28.59	82.73	0.35	3000	
H22-1	0/±45/90°	260	81.39	26.16	81.39	0.40	2800	
H22-6	0/±45/90°	260	80.36	25.64	80.36	0.45	---	gage failed
H25-1	0/±45/90°	260	88.17	26.71	88.17	0.44	---	gage failed
H25-3	0/±45/90°	260	86.27	26.16	86.27	0.36	3500	
Avg.			83.78	26.65	83.78	0.40	3100	
Std.Dev.			3.32	1.15	3.32	0.04	360	
H22-2	0/±45/90°	350	90.84	28.20	90.84	0.46	3000	
H23-3	0/±45/90°	350	89.90	33.36	89.90	0.42	2700	
H23-4	0/±45/90°	350	75.87	22.35	75.87	0.27	2500	
H27-4	0/±45/90°	350	85.86	27.39	85.86	0.39	2800	
H33-1	0/±45/90°	350	71.43	28.57	71.43	0.38	2600	
Avg.			82.78	27.98	82.78	0.38	2720	
Std.Dev.			8.69	3.92	8.69	0.07	190	
H20-4	0/±45/90°	72	67.14					Based on net cross-
H20-9	0/±45/90°	72	66.22					sectional area. Speci-
H21-6	0/±45/90°	72	61.20					mens had a 0.1935 inch
H21-10	0/±45/90°	72	65.23					diameter hole in center
H26-2	0/±45/90°	72	63.80					of gage section.
Avg.			64.72					
Std. Dev.			2.33					

Test: Tension   Material: T300/V378A

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
I16-1	0°	-67	172.4	19.31	172.4	0.33	6,800	
I16-5	0°	-67	238.3	20.12	238.3	0.29	11,040	
I17-6	0°	-67	240.8	20.28	240.8	0.29	17,200	
I17-9	0°	-67	210.0	19.53	210.0	0.31	10,300	
I17-17	0°	-67	250.0	20.90	250.0	0.31	11,300	
Avg.			222.3	20.03	222.3	0.31	10,130	
Std.Dev.			31.7	0.63	31.7	0.02	1,900	
I16-7	0°	72	189.7	19.58	189.7	0.29	9,060	
I16-8	0°	72	238.4	20.24	238.4	0.26	8,960	
I17-4	0°	72	250.6	19.71	250.6	0.32	11,800	
I17-5	0°	72	224.1	20.66	224.1	0.27	11,000	
I17-14	0°	72	248.4	20.32	248.4	0.34	11,720	
Avg.			230.2	20.10	230.2	0.30	10,510	
Std.Dev.			25.0	0.45	25.0	0.03	1,400	
I16-2	0°	350	183.9	21.73	183.9	0.31	10,440	
I16-4	0°	350	213.0	21.00	213.0	0.34	10,000	
I16-9	0°	350	189.5	20.95	189.5	0.29	8,400	
I17-3	0°	350	224.7	24.51	224.7	0.37	9,800	
I17-8	0°	350	239.4	22.50	239.4	0.36	10,200	
Avg.			210.1	22.14	210.1	0.33	9,770	
Std.Dev.			23.4	1.47	23.4	0.03	800	
I16-3	0°	450	213.4	19.37	213.4	0.29	10,360	
I16-6	0°	450	200.8	18.90	200.8	0.30	11,400	
I17-1	0°	450	208.2	18.09	208.2	0.36	11,340	
I17-12	0°	450	223.8	20.04	223.8	0.37	11,100	
I17-16	0°	450	240.3	19.47	240.3	0.29	11,700	
Avg.			217.3	18.77	217.3	0.32	11,180	
Std.Dev.			15.3	1.07	15.3	0.04	510	

Test: Tension Material: T300/V378A

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μ in/in)	Remarks
I18-5	90°	-67	6.67	1.39	6.67	---	4,875	
I18-8	90°	-67	6.69	1.41	6.69	---	4,745	
I19-1	90°	-67	4.68	1.41	4.68	---	3,365	
I20-4	90°	-67	5.12	1.41	5.12	---	4,515	
I21-8	90°	-67	5.96	1.39	5.96	---	4,225	
Avg.			5.82	1.40	5.82		4,345	
Std.Dev.			0.91	0.01	0.91		600	
I15-5	90°	72	4.74	1.27	4.74	---	3,735	
I18-2	90°	72	5.68	1.29	4.18	---	4,420	
I19-8	90°	72	6.11	1.35	2.44	---	4,685	
I20-7	90°	72	4.96	1.32	3.56	---	3,760	
I21-4	90°	72	5.33	1.30	2.85	---	4,115	
Avg.			5.37	1.31	3.55		4,140	
Std.Dev.			0.55	0.03	0.94		410	
I15-3	90°	350	4.42	1.04	3.45	---	4,275	
I18-8	90°	350	4.08	1.04	3.81	---	3,950	
I19-5	90°	350	4.97	1.08	4.09	---	4,700	
I20-9	90°	350	4.02	1.09	3.16	---	3,650	
I21-1	90°	350	4.44	1.12	3.62	---	4,085	
Avg.			4.84	1.07	3.63		4,130	
Std.Dev.			0.38	0.03	0.35		390	
I15-10	90°	450	3.48	1.03	2.08	---	3,365	
I18-7	90°	450	3.71	0.96	2.04	---	3,910	
I19-9	90°	450	4.51	1.00	2.17	---	4,640	
I20-1	90°	450	4.69	0.99	3.44	---	4,825	
I21-10	90°	450	4.66	1.01	3.03	---	4,705	
Avg.			4.21	1.00	2.55		4,290	
Std.Dev.			0.57	-0.02	0.64		630	

Test: Tension				Material: T300/V378A				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μ in/in)	Remarks
I4-6	±45°	-67	22.38	3.17	9.27	0.73	9,620	
I5-10	±45°	-67	23.12	3.35	8.63	0.71	8,800	
I6-8	±45°	-67	20.95	2.90	8.81	0.61	8,280	
I9-1	±45°	-67	20.84	3.05	7.52	0.71	10,300	
I10-5	±45°	-67	20.33	3.16	7.38	0.73	8,100	
Avg.			21.52	3.13	8.32	0.70	9,020	
Std.Dev.			1.17	0.16	0.83	0.05	930	
I4-3	±45°	72	19.18	2.97	7.36	0.60	8,000	*
I9-9	±45°	72	22.14	2.98	6.19	0.63	4,500	*
I10-7	±45°	72	21.42	2.91	6.29	0.53	12,000	
I11-5	±45°	72	21.96	2.97	6.42	0.63	9,800	*
I22-1	±45°	72	21.76	2.98	5.49	0.58	12,200	
Avg.			21.29	2.96	6.35	0.59	12,100	
Std.Dev.			1.21	0.03	0.67	0.04	---	
I8-6	±45°	350	16.26	2.39	5.36	0.93	18,200	
I9-8	±45°	350	16.17	2.64	4.04	1.08	23,600	
I10-10	±45°	350	14.96	2.41	4.83	0.95	39,400	
I11-4	±45°	350	16.77	2.58	3.95	1.03	6,800	*
I22-2	±45°	350	16.43	2.65	4.29	---	10,200	*
Avg.			16.12	2.54	4.49	1.00	27,070	
Std.Dev.			0.69	0.13	0.59	0.07	11,020	
I5-1	±45°	450	14.46	2.14	3.98	0.81	20,000	
I8-7	±45°	450	14.92	2.32	3.06	0.78	20,400	
I9-6	±45°	450	15.02	2.18	2.45	0.87	20,600	
I10-9	±45°	450	14.88	2.02	4.26	0.81	20,200	
I11-8	±45°	450	15.41	2.16	3.56	0.82	20,400	
Avg.			14.94	2.16	3.46	0.82	20,320	
Std.Dev.			0.34	0.11	0.73	0.03	230	

*Not included in ult. strain avg. and std. dev.; strain gage failed prior to end of test

Test: Tension Material: V378

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μ in/in)	Remarks
I28-4	0/±45/90	72	109.7	13.33	109.7	0.57	10,750	
I29-4	0/±45/90	72	102.6	12.26	102.6	0.58	10,200	
I37-3	0/±45/90	72	130.4	14.83	130.4	0.53	10,600	
I39-3	0/±45/90	72	125.4	14.80	125.4	0.63	10,500	
I40-3	0/±45/90	72	130.4	14.58	130.4	0.65	10,900	
Avg.			119.7	13.96	119.7	0.59	10,590	
Std.Dev.			12.8	1.13	12.8	0.05	270	
I12-3	0/±45/90	350	112.9	15.39	112.9	---	7,750	
I13-3	0/±45/90	350	107.7	9.83	107.7	0.66	10,250	
I25-3	0/±45/90	350	99.9	13.43	99.9	0.53	8,750	
I30-3	0/±45/90	350	90.3	12.54	90.3	0.58	9,000	
I40-2	0/±45/90	350	119.6	15.89	119.6	0.69	9,350	
Avg.			106.1	13.41	106.1	0.62	9,020	
Std.Dev.			11.4	2.43	11.4	0.07	910	
I12-10	0/±45/90	450	88.9	12.43	88.9	0.34	7,000	
I13-10	0/±34/90	450	102.4	13.68	102.4	0.57	9,000	
I26-3	0/±45/90	450	111.6	12.14	111.6	0.63	10,650	
I36-8	0/±45/90	450	115.3	13.86	115.3	0.50	10,000	
I38-10	0/±45/90	450	119.2	13.62	119.2	0.56	10,250	
Avg.			107.5	13.15	107.5	0.52	9,380	
Std.Dev.			12.1	0.80	12.1	0.11	1,460	
I12-1	0/±45/90	72	86.4	---	---	---	---	These specimens had a
I25-2	0/±45/90	72	79.9	---	---	---	---	0.1935 inch diameter
I30-2	0/±45/90	72	83.0	---	---	---	---	hole in the center of
I35-1	0/±45/90	72	103.7	---	---	---	---	the gage section.
I38-1	0/±45/90	72	112.5	---	---	---	---	Strength is based on
Avg.			93.1					net cross-sectional
Std.Dev.			14.2					area.

Test: Tension				Material: HyE 1076J				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
J18-3	0°	-67	198.4	20.97	198.4	0.33	9000	
J18-11	0°	-67	197.0	20.12	197.0	0.30	8900	
J18-17	0°	-67	213.5	20.68	213.5	0.29	4500	gage failed
J19-4	0°	-67	202.6	19.64	202.6	0.34	8500	
J19-8	0°	-67	172.5	20.83	172.5	0.33	8000	
Avg.			196.8	20.45	196.8	0.32	8600	excludes J18-17
Std.Dev.			15.1	0.56	15.1	0.02	450	
J18-1	0°	72	190.8	18.37	190.8	0.35	10100	
J18-5	0°	72	194.4	20.03	194.4	0.31	10700	
J18-15	0°	72	219.4	20.43	219.4	0.31	10000	
J19-1	0°	72	214.5	18.15	214.5	0.29	10800	
J19-6	0°	72	216.4	19.49	216.4	0.33	10500	
Avg.			207.1	19.29	207.1	0.32	10420	
Std.Dev.			13.4	1.00	13.4	0.02	360	
J18-4	0°	260	211.5	22.53	211.5	0.31	9500	
J18-8	0°	260	254.7	21.19	254.7	0.30	10200	
J18-12	0°	260	224.6	21.64	224.6	0.36	9500	
J19-5	0°	260	235.2	22.93	235.2	0.29	10500	
J19-7	0°	260	235.8	22.61	235.8	0.30	9800	
Avg.			232.3	22.38	232.3	0.31	9900	
Std.Dev.			15.9	0.49	15.9	0.03	440	
J19-2	0°	350	228.9	22.28	228.9	0.33	5600	gage failed
J19-3	0°	350	227.4	20.16	227.4	0.33	10700	
J18-2	0°	350	242.2	23.94	242.2	0.39	9800	
J18-10	0°	350	224.9	21.71	224.9	0.37	9600	
J18-16	0°	350	218.7	22.49	218.7	0.32	9600	
Avg.			228.4	22.12	228.4	0.35	9930	excludes J19-2
Std.Dev.			8.6	1.37	8.6	0.03	530	

Test: Tension — Material: HyE 1076J

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
J26-6	90°	-67	6.29	1.88	6.29	---	3100	
J27-3	90°	-67	3.23	1.78	3.23	---	1900	
J28-3	90°	-67	3.96	1.49	3.96	---	2500	
J29-2	90°	-67	5.31	1.68	3.11	---	3300	
J29-4	90°	-67	4.85	1.60	4.85	---	3000	
Avg.			4.73	1.69	4.29	---	2760	
Std.Dev.			1.19	0.15	1.32	---	560	
J26-1	90°	72	6.13	1.37	6.13	---	3900	
J26-5	90°	72	4.93	1.39	4.93	---	3200	
J28-1	90°	72	6.17	1.34	6.17	---	4300	
J29-1	90°	72	6.52	1.33	6.52	---	4600	
J30-2	90°	72	4.53	1.28	4.53	---	3500	
Avg.			5.66	1.34	5.66	---	3900	
Std.Dev.			0.87	0.04	0.87	---	570	
J26-8	90°	260	3.64	1.55	3.64	---	2100	
J27-8	90°	260	4.68	1.39	4.68	---	3400	
J28-9	90°	260	4.11	1.40	4.11	---	2800	
J29-8	90°	260	3.76	1.37	3.76	---	2600	
J30-7	90°	260	2.87	1.16	2.87	---	2300	
Avg.			3.81	1.37	3.81	---	2640	
Std.Dev.			0.66	0.14	0.66	---	500	
J26-3	90°	350	3.59	1.43	3.59	---	2300	
J27-2	90°	350	3.59	1.29	3.59	---	2800	
J28-5	90°	350	3.67	1.25	3.67	---	2800	
J29-5	90°	350	3.83	1.27	3.83	---	3000	
J30-3	90°	350	2.67	1.25	2.67	---	2200	
Avg.			3.47	1.30	3.47	---	2620	
Std.Dev.			0.46	0.08	0.46	---	350	

Test: Tension   Material: FyE 1076J

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
J4-3	±45°	-67	26.77	3.25	11.02	0.64	10700	
J6-2	±45°	-67	30.92	2.93	10.00	0.68	15300	
J8-2	±45°	-67	26.40	3.17	16.53	0.49	9400	
J10-2	±45°	-67	26.68	3.19	18.31	0.57	10200	
J11-3	±45°	-67	26.68	3.29	12.19	0.48	10000	
Avg.			27.49	3.16	13.61	0.57	11120	
Std.Dev.			1.92	0.14	3.62	0.09	2380	
J3-2	±45°	72	22.00	2.96	6.83	0.62	10300	gage failed
J5-6	±45°	72	22.18	3.16	6.08	0.68	13100	
J8-2	±45°	72	22.17	3.17	4.19	0.71	6200	gage failed
J11-2	±45°	72	22.73	3.00	9.25	0.65	11200	
J12-2	±45°	72	22.33	3.09	5.74	0.67	10700	
Avg.			22.28	3.08	6.42	0.67	11670	omits J3-2 & J8-2
Std.Dev.			0.28	0.10	1.85	0.03	1270	
J3-1	±45°	260	15.55	2.92	4.60	0.69	10400	
J5-1	±45°	260	15.81	3.11	3.58	0.71	14400	
J7-1	±45°	260	17.44	3.04	4.86	0.66	16200	
J9-1	±45°	260	16.90	3.41	4.64	0.79	20000	
J11-1	±45°	260	16.77	2.99	4.13	0.75	33400	
Avg.			16.49	3.09	4.36	0.73	18880	
Std.Dev.			0.79	0.19	0.51	0.05	8820	
J3-6	±45°	350	16.72	2.65	3.99	0.67	20000	gage failed
J4-2	±45°	350	16.37	2.84	5.19	0.74	32000	
J7-6	±45°	350	13.71	2.42	4.24	0.77	36800	
J9-7	±45°	350	15.33	2.81	3.78	0.70	8000	gage failed
J11-8	±45°	350	15.85	2.68	3.87	0.70	16000	gage failed
Avg.			16.60	2.68	4.21	0.71	34400	only J4-2 & J7-6 included
Std.Dev.			1.29	0.17	0.57	0.04	---	

Test: Tension				Material: HyE 1076J				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
J15-6	0/±45/90°	72	108.9	10.49	108.9	0.37	10200	
J17-5	0/±45/90°	72	115.0	11.00	115.0	0.36	10200	
J21-6	0/±45/90°	72	121.4	11.64	121.4	0.36	11000	
J23-4	0/±45/90°	72	110.8	11.17	110.8	0.39	10300	
J25-5	0/±45/90°	72	128.1	11.66	128.1	0.37	11400	
Avg.			116.8	11.19	116.8	0.37	10620	
Std.Dev.			7.9	0.49	7.9	0.01	550	
J13-6	0/±45/90°	260	112.2	12.46	112.2	0.45	8300	
J14-7	0/±45/90°	260	127.0	11.03	127.0	0.37	10300	
J17-4	0/±45/90°	260	121.1	12.36	121.1	0.39	10400	
J21-8	0/±45/90°	260	123.9	12.64	123.9	0.42	9900	
J23-5	0/±45/90°	260	116.2	12.50	116.2	0.39	9400	
Avg.			120.1	12.20	120.1	0.40	9780	
Std.Dev.			5.9	0.66	5.9	0.03	630	
J14-6	0/±45/90°	350	109.3	10.87	109.3	0.38	10500	
J16-6	0/±45/90°	350	114.2	11.24	114.2	0.29	9900	
J20-6	0/±45/90°	350	119.8	12.17	119.8	0.37	9500	
J22-6	0/±45/90°	350	126.3	12.83	126.3	0.37	7600	gage failed
J24-4	0/±45/90°	350	121.1	12.36	121.1	0.38	9700	
Avg.			118.1	11.89	118.1	0.36	9900	omits J22-6
Std.Dev.			6.6	0.81	6.6	0.04	430	omits J22-6
J13-2	0/±45/90°	72	86.8					These specimens had a
J14-2	0/±45/90°	72	93.4					0.1935 inch diameter
J16-2	0/±45/90°	72	99.1					hole in the center of
J21-2	0/±45/90°	72	84.5					the gage section. Strength
J25-1	0/±45/90°	72	78.6					is based on net cross-
Avg.			88.5					sectional area.
Std.Dev.			8.0					

Test: Tension **Material: G-160/6535-1**

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
K12-4	0°	-67	213.8	18.39	213.8	0.35	11500	
K12-8	0°	-67	154.8	17.80	154.8	0.29	8450	
K13-1	0°	-67	176.4	18.65	176.4	0.37	9250	
K13-8	0°	-67	168.8	19.23	168.8	0.28	8900	
K13-5	0°	-67	148.3	18.39	148.3	0.27	7800	
Avg.			172.4	18.49	172.4	0.31	9180	
Std.Dev.			25.7	0.52	25.7	0.04	1410	
K12-2	0°	72	170.6	18.94	170.6	0.31	8500	
K12-6	0°	72	174.0	18.09	174.0	0.31	9100	
K13-4	0°	72	164.3	17.64	164.3	0.31	8640	
K13-14	0°	72	180.0	19.05	180.0	0.34	9000	
K13-7	0°	72	148.4	18.98	148.4	0.33	7400	
Avg.			167.5	18.54	167.5	0.32	8530	
Std.Dev.			12.1	0.64	12.1	0.01	680	
K12-1	0°	260	161.7	20.51	156.0	0.33	9100	
K12-5	0°	260	166.0	22.02	166.0	0.36	8400	
K13-3	0°	260	166.8	20.37	166.8	0.38	7900	
K13-10	0°	260	168.6	21.26	168.6	0.35	7100	
K13-17	0°	260	150.0	21.39	150.0	0.38	6700	
Avg.			162.6	21.11	161.5	0.36	7820	
Std.Dev.			7.5	0.68	8.1	0.02	940	
K12-3	0°	350	190.0	19.74	170.7	0.22	9450	
K12-7	0°	350	151.9	19.59	148.4	0.30	8000	
K13-2	0°	350	194.2	19.05	194.2	0.24	9350	
K13-9	0°	350	176.7	19.79	176.3	0.36	8650	
K13-16	0°	350	143.9	21.27	143.9	0.41	6500	
Avg.			171.3	19.89	166.7	0.31	8390	
Std.Dev.			22.5	0.82	20.7	0.08	1210	

Test: Tension Material: G-160/6535-1

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
K14-2	90°	-67	5.15	2.41	2.04	---	2260	
K15-3	90°	-67	5.36	2.61	1.47	---	2190	
K16-3	90°	-67	4.39	2.25	1.20	---	1980	
K17-3	90°	-67	4.30	2.31	1.60	---	1890	
K18-3	90°	-67	5.43	1.76	1.78	---	3160	
Avg.			4.93	2.27	1.58	---	2290	
Std.Dev.			0.54	0.31	0.35	---	500	
K45-1	90°	72	6.15	1.52	6.15	---	3940	
K15-1	90°	72	5.36	1.69	5.36	---	3090	
K16-1	90°	72	5.33	2.11	5.33	---	3090	
K17-1	90°	72	5.19	1.69	5.19	---	3040	
Avg.			5.51	1.82	5.51	---	3290	
Std.Dev.			0.43	0.27	0.43	---	440	
K15-4	90°	260	3.09	1.73	0.81	---	1820	
K16-4	90°	260	4.28	1.78	0.94	---	2600	
K17-4	90°	260	4.43	1.70	4.43	---	2610	
K18-4	90°	260	3.72	1.33	3.72	---	2690	
K45-3	90°	260	3.90	1.39	3.90	---	2710	
Avg.			3.88	1.59	2.70	---	2490	
Std.Dev.			0.53	0.21	1.74	---	380	
K15-2	90°	350	2.42	1.79	1.97	---	1360	
K16-2	90°	350	3.27	1.61	3.27	---	2035	
K17-2	90°	350	3.86	1.61	1.89	---	2510	
K45-2	90°	350	4.41	1.53	2.57	---	3200	
Avg.			3.49	1.63	2.42	---	2270	
Std.Dev.			0.85	0.11	0.64	---	780	

Test: Tension				Material: G-160/6535-1				
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
K4-4	±45	-67	18.72	3.20	10.70	0.55	6520	
K6-2	±45	-67	19.71	3.14	7.73	0.62	6950	
K7-4	±45	-67	20.88	3.13	7.50	0.63	9200	
K10-3	±45	-67	16.88	3.28	9.64	0.62	5650	
K11-1	±45	-67	18.95	3.63	12.11	0.66	6120	
Avg.			19.43	3.28	9.53	0.62	6890	
Std.Dev.			0.90	0.21	1.96	0.04	1380	
K5-1	±45	72	17.70	3.15	8.40	0.68	7600	
K6-1	±45	72	16.36	3.29	4.96	0.73	6400	
K7-1	±45	72	15.36	3.13	5.46	0.60	6200	
K8-1	±45	72	17.77	2.99	5.26	0.66	8100	
K9-1	±45	72	15.45	3.02	5.54	0.60	6400	
Avg.			16.53	3.12	5.92	0.65	6940	
Std.Dev.			1.17	0.12	1.41	0.05	850	
K4-2	±45	260	[illegible]47	2.85	4.48	0.73	12200	
K5-2	±45	260	15.[illegible]	3.09	3.58	0.61	12800	
K7-2	±45	260	15.91	3.06	4.76	0.72	13700	
K9-2	±45	260	15.75	3.13	4.63	0.79	10700	
K10-1	±45	260	14.88	3.11	5.60	0.75	8200	
Avg.			15.56	3.05	4.61	0.72	11520	
Std.Dev.			0.41	0.12	0.72	0.07	2150	
K4-3	±45	350	15.52	2.70	3.79	0.72	26200	
K5-3	±45	350	17.48	2.81	4.15	0.68	18000+	gage failed
K7-3	±45	350	17.32	2.91	4.46	0.70	6000+	gage failed
K9-3	±45	350	17.01	2.81	4.01	0.75	43400	
K10-2	±45	350	15.08	2.73	3.82	0.75	7200+	gage failed
Avg.			16.48	2.79	4.05	0.72	34800	excludes K5-3,K7-3,K10-2
Std.Dev.			1.10	0.08	0.28	0.03		

Test: Tension   Material: G-160/6535-1

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (ksi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ultimate Strain (μin/in)	Remarks
K34-3	0/±45[1]	72	88.27	9.76	88.27	0.59	8200	
K35-4	0/±45[1]	72	94.23	11.54	94.23	0.67	7000	
K35-6	0/±45[1]	72	99.62	12.67	99.62	0.62	8500	
K36-3	0/±45[1]	72	103.21	10.99	103.21	0.58	8690	
K36-7	0/±45[1]	72	101.08	12.07	101.08	0.66	8450	
Avg.			97.28	11.41	97.28	0.62	8170	
Std.Dev			6.03	1.11	6.03	0.04	680	
K37-3	0/±45/90[2]	72	98.21	11.60	98.21	0.42	8220	
K37-7	0/±45/90[2]	72	90.40	11.76	90.40	0.42	7540	
K38-3	0/±45/90[2]	72	87.10	12.53	87.10	0.39	6950	
K38-9	0/±45/90[2]	72	101.99	11.39	101.99	0.43	8720	
K39-4	0/±45/90[2]	72	79.90	10.68	79.90	0.40	7250	
Avg.			91.52	11.59	91.52	0.41	7740	
Std.Dev.			8.81	0.67	8.81	0.02	720	
K24-1	0/±45/90[3]	72	100.72	10.74	100.72	0.36	9160	
K24-10	0/±45/90[3]	72	88.22	10.95	88.22	0.37	8080	
K25-1	0/±45/90[3]	72	90.76	11.04	90.76	0.36	8200	
K25-10	0/±45/90[3]	72	89.90	10.87	89.90	0.36	7880	
K26-1	0/±45/90[3]	72	84.78	11.00	84.78	0.40	7730	
Avg.			90.88	10.92	90.88	0.37	8210	
Std.Dev.			5.96	0.12	5.96	0.02	560	

[1] $(0,45,-45,0,0,-45,45,0)_s$-16 ply; [2] $(0,90,45,-45,0,0,-45,45,0,0)_s$-20 ply; [3] $(0,45,-45,0,0,-45,45,0,90,0)_s$-20 ply

APPENDIX E
COMPRESSION DATA

All of the compression data generated during this program are presented in this section. They are summarized in tabular and graphical form in Sections 4.1 through 4.6.

Test: Compression				Material: T300/AFR800			
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (μ in/in)	Remarks
F35-12	0°	-67	224.8	17.93	84.8	25,000	
F35-13	0°	-67	208.3	19.91	69.4	22,500	
F35-14	0°	-67	190.0	17.80	48.0	14,500	
F35-19	0°	-67	218.2	22.67	54.0	11,500	
F36-2	0°	-67	186.4	17.43	74.1	18,000	
Avg.			205.6	19.15	66.1	18,300	
Std.Dev.			17.0	2.19	15.0	5,600	
F35-4	0°	72	145.6	19.77	19.8	9,600	
F35-5	0°	72	189.3	17.52	19.8	11,800	
F35-7	0°	72	192.9	12.21	33.3	20,800	
F35-9	0°	72	159.8	15.26	112.3	13,000	
F35-11	0°	72	185.6	15.14	38.6	18,500	
Avg.			174.6	15.98	44.8	14,700	
Std.Dev.			23.0	2.85	38.7	4,700	
F35-6	0°	260	149.5	16.97	59.4	11,300	
F35-8	0°	260	194.1	15.40	119.1	16,300	
F36-1	0°	260	220.5	22.90	48.7	13,700	
F36-3	0°	260	167.6	15.99	102.7	15,800	
F36-4	0°	260	209.5	20.64	47.0	15,000	
Avg.			188.2	18.38	75.4	14,400	
Std.Dev.			29.4	3.24	33.3	2,000	
F35-1	0°	350	163.7	17.11	63.9	9,800	
F35-10	0°	350	206.3	23.86	56.8	9,800	
F35-15	0°	350	157.4	19.53	41.5	7,300	
F35-16	0°	350	130.4	22.58	31.1	6,700	
F36-11	0°	350	163.3	20.45	163.3	8,100	
Avg.			164.2	20.71	71.3	8,300	
Std.Dev.			27.2	2.64	53.0	1,400	

Test: Compression **Material:** T300/AFR800

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (μ in/in)	Remarks
F35-3	90°	-67	29.5	1.87	10.1	39,800	
F35-5	90°	-67	40.5	1.78	12.6	28,800	
F35-15	90°	-67	42.3	1.41	25.6	37,300	
F35-23	90°	-67	55.3	1.49	11.1	26,800	
F36-9	90°	-67	23.9	1.96	9.0	25,000	
Avg.			38.4	1.70	13.7	31,500	
Std.Dev.			12.4	0.24	6.8	6,600	
F36-6	90°	72	39.1	2.91	39.1	14,800	
F36-8	90°	72	40.8	2.22	40.8	13,500+	Evidence of buckling
F36-14	90°	72	40.3	2.58	6.0	31,000	
F36-18	90°	72	45.7	2.44	45.1	21,000	
F36-23	90°	72	32.4	2.30	32.5	9,100+	Evidence of buckling
Avg.			39.7	2.50	32.8	17,900+	
Std.Dev.			4.8	0.27	15.7	9,000	
F35-15	90°	260	29.9	1.40	29.9	9,800	
F35-21	90°	260	26.7	1.57	23.9	9,800+	Evidence of buckling
F35-27	90°	260	29.2	1.40	1.9	20,000	
F36-2	90°	260	27.0	1.55	10.4	13,700	
F36-15	90°	260	29.2	1.58	29.2	10,000+	Evidence of buckling
Avg.			28.4	1.50	18.9	12,700+	
Std.Dev.			1.5	0.09	12.4	4,400	
F35-1	90°	350	25.1	1.44	9.8	34,300	
F35-11	90°	350	27.5	1.91	27.5	13,300	
F35-24	90°	350	23.0	1.56	11.0	33,300	
F35-30	90°	350	32.7	2.77	32.7	21,800	
F36-14	90°	350	30.4	2.42	30.4	35,300	
Avg.			27.7	2.02	22.3	25,800	
Std.Dev.			3.9	0.57	11.0	9,800	

Test: Compression **Material:** SiC/5506

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (μ in/in)	Remarks
G42-1	0°	-67	400.1	33.06	275.6	9,300 +	Evidence of buckling
G42-7	0°	-67	396.3	33.06	295.3	15,700	
G42-11	0°	-67	434.9	33.04	184.4	16,900	
G42-17	0°	-67	387.8	28.96	305.0	15,400	
G42-19	0°	-67	334.7	37.29	160.3	7,300 +	Evidence of buckling
Avg.			390.8	33.08	244.1	12,920 +	
Std.Dev.			36.1	2.95	66.9	4,310	
G42-2	0°	72	338.0	32.01	81.6	5,400+	Tabs debonded. Retabbed with
G42-4	0°	72	350.0	34.94	82.5	4,500+	different adhesive and tests
G42-6	0°	72	305.4	39.77	--	6,250+	rerun.
G42-8	0°	72	322.4	34.58	--	5,900+	
G42-10	0°	72	332.7	36.28	177.3	9,100+	
Avg.			329.7	35.52	113.8	6,220+	
Std.Dev.			16.8	2.84	55.0	1,730	
G42-12	0°	260	228.8	34.17	102.8	7,200	
G42-14	0°	260	233.2	39.09	182.0	7,800	
G42-16	0°	260	220.6	30.74	164.8	8,800	
G42-18	0°	260	240.3	31.79	124.6	6,200	
G42-20	0°	260	239.1	33.53	131.4	8,800	
Avg.			232.4	33.86	141.1	7,760	
Std.Dev.			8.1	3.22	31.9	1,110	
G42-3	0°	350	153.3	34.18	82.5	3,800 +	Evidence of buckling
G42-5	0°	350	97.3	27.38	91.3	3,700	
G42-9	0°	350	102.5	27.43	100.8	3,700	
G42-13	0°	350	146.9	46.96	106.1	3,050 +	Evidence of buckling
G42-15	0°	350	154.3	33.81	95.1	3,530	
Avg.			130.9	33.95	95.2	3,560 +	
Std.Dev.			28.5	7.98	9.0	300	

Test: Compression				Material: SiC/5506			
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (μ in/in)	Remarks
G42-15	90°	-67	56.6	3.97	11.0	19,200	
G42-26	90°	-67	57.7	4.34	13.4	18,100	
G42-36	90°	-67	53.4	3.84	14.4	24,100	
G42-46	90°	-67	53.7	2.97	11.0	25,700	
G42-52	90°	-67	62.3	1.93	27.9	23,900	
Avg.			56.7	3.41	15.5	22,200	
Std.Dev.			3.6	0.97	7.1	3,340	
G42-1	90°	72	34.1	4.38	8.7	4,100+	evidence of buckling
G42-14	90°	72	31.8	3.30	11.6	7,000+	evidence of buckling
G42-27	90°	72	35.5	3.03	30.5	12,000	
G42-32	90°	72	34.4	4.05	15.1	6,900+	evidence of buckling
G42-45	90°	72	36.3	3.13	24.2	16,200	
Avg.			34.4	3.58	18.0	9,240+	
Std.Dev.			1.7	0.60	9.1	4,820	
G42-7	90°	260	26.9	2.54	14.0	16,700+	evidence of buckling
G42-17	90°	260	26.7	2.41	16.9	24,200	
G42-18	90°	260	23.0	2.39	10.6	23,400	
G42-21	90°	260	25.9	2.22	11.9	21,700	
G42-35	90°	260	25.7	2.44	17.9	16,700+	evidence of buckling
Avg.			25.7	2.40	14.3	20,540+	
Std.Dev.			1.5	0.12	3.2	3,620	
G42-6	90°	350	21.6	1.87	9.8	24,800	
G42-10	90°	350	18.7	1.83	7.4	31,200	
G42-25	90°	350	20.4	1.43	10.5	24,700	
G42-35	90°	350	18.8	1.94	12.4	6,600+	evidence of buckling
G42-37	90°	350	19.3	2.34	7.0	27,700	
Avg.			19.8	1.88	9.4	27,100*	*excludes G42-35
Std.Dev.			1.2	0.32	2.2	3,070*	

Test: Compression **Material:** HyE 2034D

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (μ in/in)	Remarks
H29-2	0°	-67	61.24	42.29	28.45	2000	
H29-8	0°	-67	53.27	38.57	39.14	1400	
H29-13	0°	-67	56.64	37.19	44.34	1700	
H29-17	0°	-67	52.02	33.96	34.88	1900	
H29-22	0°	-67	45.87	33.12	31.47	1700	
Avg.			53.81	37.03	35.66	1740	
Std.Dev.			5.69	3.70	6.28	230	
H29-12	0°	72	41.91	39.91	39.81	1100	
H29-16	0°	72	47.41	37.64	38.09	1500	
H30-1	0°	72	44.60	64.00	14.40	1000	
H30-5	0°	72	53.08	41.15	12.55	1700	
H30-8	0°	72	55.56	46.78	24.00	1200	
Avg.			48.51	45.90	25.77	1300	
Std.Dev.			5.71	10.67	12.81	290	
H29-4	0°	260	31.16	54.53	13.90	1100	
H29-9	0°	260	43.60	46.84	14.34	1200	
H30-2	0°	260	48.00	46.65	19.18	1200	
H30-7	0°	260	46.32	38.92	32.65	1400	
H30-11	0°	260	40.93	34.49	33.68	1700	
Avg.			42.00	44.29	22.75	1320	
Std.Dev.			6.63	7.77	9.73	240	
H29-1	0°	350	48.53	55.78	20.08	1200	*H29-11 broke at end, just inside
H29-7	0°	350	42.99	46.18	29.90	1100	gripping tabs. All others broke
H29-11	0°	350	8.73*	40.40	8.49*	200*	in center of gage section.
H29-14	0°	350	32.21	41.90	16.98	1200	
H29-20	0°	350	44.38	32.86	34.14	1200	
Avg.			42.03**	43.42	25.28**	1180**	**excludes H29-11
Std.Dev.			6.96	8.42	8.08	50	

Test: Compression				Material: HyE 2034D			
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (μ in/in)	Remarks
H29-6	90°	-67	15.12	1.00	5.48	18500	
H29-11	90°	-67	20.41	1.23	15.59	18800	
H29-10	90°	-67	20.88	2.18	2.30	21100	
H30-2	90°	-67	19.92	2.65	3.67	21500	
H29-2	90°	-67	---	---	---	---	Broke in mounting
Avg.			19.08	1.76	6.76	19980	
Std.Dev.			2.67	0.78	6.03	1540	
H29-19	90°	72	16.00	1.77	1.53	30100	
H29-23	90°	72	3.35	---	2.33	3200	Probable damage before testing
H30-3	90°	72	15.07	1.36	2.22	53500	
H30-7	90°	72	16.73	1.48	2.15	34400	
H30-9	90°	72	22.38	1.88	6.80	25800	
Avg.			17.55	1.62	3.17	35950	Averages exclude H29-23
Std.Dev.			3.30	0.24	2.44	12220	
H30-14	90°	260	12.58	0.78	1.56	14700	
H30-19	90°	260	12.17	1.40	12.17	8000	
H29-20	90°	260	12.08	1.07	12.08	12300	
H29-25	90°	260	14.69	1.45	2.04	15900	
H29-34	90°	260	13.72	1.47	5.02	18500	
Avg.			13.05	1.24	6.58	13880	
Std.Dev.			1.13	0.30	5.22	3970	
H29-22	90°	350	12.50	0.90	4.56	22700	
H29-29	90°	350	11.50	0.92	2.11	19400	
H29-16	90°	350	8.75	1.09	1.86	21900	
H29-28	90°	350	12.25	0.76	1.44	31400	
H29-7	90°	350	12.43	0.95	0.99	29800	
Avg.			11.49	0.92	2.19	25040	
Std.Dev.			1.58	0.12	1.39	5250	

Test: Compression					Material: T300/V378A		
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (μ in/in)	Remarks
I41-2	0°	-67	220.4	18.15	64.7	20,500	
I41-4	0°	-67	238.1	19.96	48.2	8,700+	evidence of buckling
I41-9	0°	-67	213.2	19.83	25.0	9,500+	evidence of buckling
I41-16	0°	-67	189.7	17.85	51.3	17,100	
I41-23	0°	-67	205.7	21.99	37.1	8,900+	evidence of buckling
Avg.			213.4	19.56	45.3	12,940	
Std.Dev.			17.9	1.66	15.0	5,490	
I41-7	0°	72	193.2	19.49	44.8	17,000	
I41-13	0°	72	168.5	20.95	53.6	16,300	
I41-22	0°	72	212.8	19.83	212.8	11,000+	evidence of buckling
I41-27	0°	72	190.6	19.25	190.6	16,600	
I41-60	0°	72	198.2	19.35	198.2	19,700	
Avg.			192.7	19.78	140.0	16,120+	
Std.Dev.			16.0	0.60	83.3	3,170	
I41-3	0°	350	169.7	24.00	169.7	6,400	
I41-11	0°	350	162.4	21.21	162.4	5,900	
I41-15	0°	350	146.9	23.91	146.9	6,200	
I41-20	0°	350	195.0	23.09	71.1	12,000	
I41-25	0°	350	135.8	24.75	66.5	10,100	
Avg.			162.1	23.39	123.3	8,120	
Std.Dev.			22.4	1.35	50.5	2,760	
I41-6	0°	450	145.9	20.03	145.9	7,800	
I41-8	0°	450	79.4	21.35	70.9	4,100	
I41-12	0°	450	87.2	17.28	87.2	5,000	
I41-18	0°	450	100.4	23.00	100.4	4,600	
I41-24	0°	450	90.3	22.49	23.2	4,180	
Avg.			100.6	20.83	85.5	5,140	
Std.Dev.			26.4	2.29	44.6	1,530	

Test: Compression					Material:	T300/V378A	
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (μ in/in)	Remarks
I42-20	90°	-67	54.7	3.83	10.1	23,600	
I42-24	90°	-67	32.4	1.52	32.4	25,000	
I42-28	90°	-67	45.2	3.27	3.2	27,500	
I42-32	90°	-67	28.2	1.65	28.2	29,500	
I42-36	90°	-67	28.9	2.26	6.8	11,500 +	evidence of buckling
Avg.			37.9	2.51	16.1	23,360 +	
Std.Dev.			11.6	1.01	13.2	7,170	
I42-2	90°	72	24.6	2.54	4.5	25,200	evidence of buckling or gage fail
I42-6	90°	72	28.2	3.86	6.5	23,200	
I42-10	90°	72	28.5	3.09	4.2	23,100	
I42-14	90°	72	24.4	1.97	4.9	12,800	
I42-18	90°	72	28.1	1.71	9.7	34,800	
Avg.			26.8	2.53	5.9	23,820	
Std.Dev.			2.1	0.87	2.3	7,820	
I42-40	90°	350	17.8	1.41	6.7	15,500+	evidence of buckling
I42-44	90°	350	18.8	1.61	4.2	13,500	
I42-48	90°	350	20.2	1.95	4.4	6,800+	evidence of buckling & gage failed
I42-52	90°	350	21.8	1.59	3.9	18,100+	evidence of buckling
I42-56	90°	350	16.3	1.25	7.0	15,200	
Avg.			19.0	1.56	5.2	13,820+	
Std.Dev.			2.1	0.26	1.5	4,260	
I42-8	90°	450	25.5	1.30	3.1	29,800	
I42-12	90°	450	21.0	1.19	5.8	42,500	
I42-13	90°	450	17.6	1.19	3.7	17,900	
I42-16	90°	450	18.3	1.07	18.3	7,290+	evidence of buckling
I42-17	90°	450	18.7	1.26	3.1	29,800	
Avg.			20.2	1.20	6.8	18,880+	
Std.Dev.			3.2	0.09	6.5	16,870	

Test: Compression **Material:** HyE 1076J

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (μ in/in)	Remarks
J32-4	0°	-67	210.8	18.79	66.1	9900+	evidence of buckling
J32-8	0°	-67	253.5	21.41	69.3	13100+	evidence of buckling
J32-13	0°	-67	195.7	19.34	83.0	20000	
J32-15	0°	-67	225.0	20.33	70.8	18500	
J32-21	0°	-67	231.9	29.57	30.0	10800+	evidence of buckling
Avg.			223.4	21.89	63.8	14500+	
Std.Dev.			21.8	4.41	20.0	4600	
J32-2	0°	72	161.9	17.30	67.5	19600	
J32-7	0°	72	248.1	21.87	173.2	11200+	evidence of buckling
J32-12	0°	72	221.9	21.83	62.2	10600	
J32-18	0°	72	245.0	22.31	245.0	11800+	evidence of buckling
J32-25	0°	72	214.2	25.46	35.7	9500	
Avg.			218.2	21.75	116.7	12500+	
Std.Dev.			34.7	2.91	88.9	4000	
J32-1	0°	260	111.1	12.55	111.1	6300+	evidence of buckling
J32-6	0°	260	205.2	23.67	64.4	8000+	evidence of buckling
J32-11	0°	260	193.7	25.52	46.3	10600	
J32-17	0°	260	161.6	26.23	31.5	6800	
J32-23	0°	260	182.9	19.13	61.0	12600	
Avg.			170.9	21.42	62.9	8900+	
Std.Dev.			37.1	5.68	30.0	2700	
J32-3	0°	350	167.7	19.12	68.8	14000	
J32-10	0°	350	124.2	26.71	52.8	5000	
J32-16	0°	350	185.6	21.15	63.9	12000	
J32-20	0°	350	184.2	25.09	115.9	9500	
J32-27	0°	350	130.8	22.54	130.8	6500	
Avg.			158.5	22.92	86.4	9400	
Std.Dev.			29.3	3.03	34.6	3700	

Test: Compression					Material: HyE 1076J		
Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (μ in/in)	Remarks
J31-5	90°	-67	35.5	2.12	7.8	13000	
J31-18	90°	-67	32.3	2.18	13.2	25900	
J31-22	90°	-67	44.9	1.46	7.5	27400	
J31-33	90°	-67	36.0	1.85	15.0	16400+	evidence of buckling
J31-49	90°	-67	26.7	1.61	6.0	27700	
Avg.			35.1	1.84	9.9	22100+	
Std.Dev.			6.6	0.31	3.9	6400	
J31-19	90°	72	31.9	1.73	9.3	35300	
J31-29	90°	72	30.8	1.42	12.6	46300	
J31-34	90°	72	29.0	1.36	9.5	37600	
J31-43	90°	72	26.7	1.48	2.4	7900+	evidence of buckling
J31-51	90°	72	31.4	1.32	12.7	34400	
Avg.			30.8	1.46	11.0	32300+	
Std.Dev.			1.3	0.16	1.9	14400	
J31-9	90°	260	24.1	1.52	3.8	13800	
J31-21	90°	260	25.7	3.03	4.0	---	gage failed
J31-31	90°	260	21.5	1.59	4.5	---	gage failed
J31-46	90°	260	22.3	1.37	4.0	21400	
J31-55	90°	260	19.4	1.69	6.3	9600+	evidence of buckling
Avg.			22.6	1.84	4.5	17600*	*excludes J31-55
Std.Dev.			2.4	0.68	1.0	---	
J31-2	90°	350	22.8	1.65	7.4	21300	
J31-15	90°	350	19.4	1.88	3.7	7700+	evidence of buckling
J31-23	90°	350	17.4	2.02	3.2	6900+	evidence of buckling
J31-39	90°	350	18.7	1.40	11.8	20000	
J31-50	90°	350	17.3	1.25	9.4	15300+	evidence of buckling
Avg.			19.1	1.64	7.1	14200+	
Std.Dev.			2.2	0.32	3.7	6700	

Test: Compression **Material:** G-160/6535-1

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (μ in/in)	Remarks
K21-3	0°	-67	230.8	19.26	63.95	11,850	
K21-7	0°	-67	192.4	22.02	72.55	8,400	
K21-13	0°	-67	235.4	21.13	69.86	10,100+	Evidence of buckling
K21-18	0°	-67	198.0	20.16	86.96	6,400+	Evidence of buckling
K21-23	0°	-67	213.6	20.14	76.10	10,850+	Evidence of buckling
Avg.			214.0	20.54	73.88	9,520+	
Std.Dev.			19.1	1.06	8.55	2,200	
K21-2	0°	72	209.6	17.09	88.5	14,200	
K21-8	0°	72	216.7	20.83	156.6	15,500	
K21-12	0°	72	207.2	19.51	122.4	8,600+	Evidence of buckling
K21-17	0°	72	204.0	19.28	90.0	19,000	
K21-22	0°	72	223.9	19.32	73.9	16,700	
Avg.			212.3	19.21	106.3	14,800+	
Std.Dev.			8.0	1.34	33.2	3,890	
K21-1	0°	260	192.3	18.76	---	9,100+	Evidence of buckling
K21-6	0°	260	206.3	19.84	75.0	12,100	
K21-11	0°	260	184.8	19.16	95.8	13,700	
K21-16	0°	260	204.3	19.76	---	9,800+	Evidence of buckling
K21-21	0°	260	156.5	16.10	71.7	10,600	
Avg.			188.8	18.73	80.9	11,060+	
Std.Dev.			20.1	1.53	13.1	1,850	
K21-4	0°	350	152.0	18.18	88.9	9,600	
K21-9	0°	350	163.0	23.13	132.8	8,500	
K21-14	0°	350	135.4	22.30	94.0	8,200	
K21-19	0°	350	145.8	23.90	75.5	7,000	
K21-24	0°	350	160.7	19.51	118.4	9,350	
Avg.			151.4	21.40	101.9	8,530	
Std.Dev.			11.3	2.45	23.2	1,030	

Test: Compression　　Material: G-160/6535-1

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ultimate Strength (10^3psi)	Initial Modulus (10^6psi)	Stress at Prop.Lim. (10^3psi)	Ultimate Strain (μ in/in)	Remarks
K19-3	90°	-67	32.7	1.88	9.8	32,600	
K19-25	90°	-67	39.3	2.06	18.8	22,800+	Evidence of buckling
K19-41	90°	-67	33.4	2.21	10.7	23,200	
K44-4	90°	-67	29.7	2.09	13.6	20,000+	Evidence of buckling
K44-27	90°	-67	45.5	1.81	17.3	30,050+	Evidence of buckling
Avg.			36.1	2.01	14.1	25,730+	
Std.Dev.			6.3	0.16	4.0	5,330	
K19-5	90°	72	30.2	1.57	15.5	25,800	
K19-27	90°	72	22.6	1.91	11.8	7,200+	Evidence of buckling
K19-45	90°	72	30.2	2.02	12.5	36,000	
K44-1	90°	72	27.0	2.64	12.1	8,600+	Evidence of buckling
K44-22	90°	72	25.0	---	14.0	32,200	
Avg.			27.0	2.04	13.2	21,960+	
Std.Dev.			3.3	0.45	1.5	13,350	
K19-1	90°	260	25.4	1.42	20.2	14,600+	Evidence of buckling
K19-11	90°	260	24.2	1.43	15.5	13,700+	Evidence of buckling
K19-40	90°	260	22.0	1.33	14.3	26,300	
K44-3	90°	260	23.7	1.29	12.9	12,800+	Evidence of buckling
K44-25	90°	260	24.5	1.56	16.5	10,900+	Evidence of buckling
Avg.			24.0	1.40	15.9	15,660+	
Std.Dev.			1.3	0.10	2.8	6,100	
K19-4	90°	350	19.8	1.87	11.9	17,000+	Evidence of buckling
K19-26	90°	350	26.3	2.12	10.4	14,800	
K19-42	90°	350	19.0	2.19	14.3	7,000+	Evidence of buckling
K44-2	90°	350	16.6	1.63	10.7	7,230+	Evidence of buckling
K44-23	90°	350	17.1	1.21	9.6	12,700+	Evidence of buckling
Avg.			19.8	1.80	11.4	11,750+	
Std.Dev.			3.9	0.40	1.9	4,490	

APPENDIX F
FLEXURE DATA

All of the flexure data generated during this program are listed in this appendix. Summaries of these data are tabulated in Sections 4.1 through 4.6.

Test: Flexure				L/D Ratio: 32:1	
Materials: T300/AFR800					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (ksi)	Modulus of Elasticity (10^6psi)	Remarks
F19-5	0°	-67	299.7	21.24	4 pt./tensile failure
F19-8	0°	-67	291.5	20.59	on lower surface
F19-12	0°	-67	295.9	19.77	
F19-15	0°	-67	292.6	20.73	
F20-3	0°	-67	278.1	18.24	
Avg.			291.6	20.11	
Std. Dev.			8.2	1.17	
F19-2	0°	72	282.0	21.68	4 pt./tensile failure
F19-7	0°	72	280.2	20.69	on lower surface
F19-17	0°	72	272.9	20.56	
F19-20	0°	72	284.9	20.94	
F20-6	0°	72	280.7	19.63	
Avg.			280.1	20.70	
Std. Dev.			4.4	0.74	
F19-0	0°	260	182.4	15.23	3 pt./specimens
F19-10	0°	260	225.8	17.18	snapped in half
F19-22	0°	260	202.5	16.11	
F20-1	0°	260	248.6	19.18	
Avg.			214.8	16.92	
Std.Dev.			28.7	1.70	
F19-14	0°	260	206.5	20.22	4 pt./delamination
F19-16	0°	260	206.8	21.06	failures
F19-19	0°	260	230.0	20.99	
F19-23	0°	260	224.8	21.27	
F19-24	0°	260	223.1	20.57	
Avg.			218.2	20.82	Shear stress at
Std.Dev.			10.9	0.42	failure = 6890 psi

Test: Flexure				L/D Ratio: 32:1	
Materials: T300/AFR800					
Specimen Number	Fiber Orientation	Test Temp. (°F)	Ultimate Strength (ksi)	Modulus of Elasticity (10^6psi)	Remarks
F19-1	0°	350	184.0	16.72	3 pt./Compr.
F19-11	0°	350	162.6	17.05	3 pt./Compr.&Delam.
F19-13	0°	350	167.2	17.23	3 pt./Compr.
F19-21	0°	350	168.4	17.40	3 pt./Compr.
F20-4	0°	350	181.1	17.72	3 pt./Compr.&Delam.
Avg.			172.7	17.22	shear stress at
Std. Dev.			9.3	0.37	failure = 2560 psi
F19-3	0°	350	181.5	19.70	4 pt./delamination
F19-9	0°	350	187.3	20.16	failures
F19-18	0°	350	181.3	19.74	
F20-2	0°	350	192.5	20.06	
F20-5	0°	350	191.5	20.05	
Avg.			186.8	19.94	shear stress at
Std.Dev.			5.3	0.21	failure = 5880 psi

Test: Flexure				L/D Ratio: 32:1	
Materials: T300/AFR800					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (ksi)	Modulus of Elasticity (10^6psi)	Remarks
F19-4	90°	-67	13.98	---	4 pt. loading
F20-5	90°	-67	17.71	1.70	
F20-15	90°	-67	13.02	1.73	
F20-19	90°	-67	15.03	1.59	
F20-26	90°	-67	14.76	1.64	
Avg.			14.90	1.67	
Std.Dev.			1.75	0.06	
F19-2	90°	72	14.43	1.34	4 pt. loading
F20-4	90°	72	14.15	1.24	
F20-12	90°	72	13.57	1.25	
F20-20	90°	72	13.95	1.26	
F20-24	90°	72	14.42	1.24	
Avg.			14.10	1.27	
Std.Dev.			0.36	0.04	
F19-5	90°	260	10.42	1.09	4 pt. loading
F20-8	90°	260	10.83	1.14	
F20-13	90°	260	10.21	1.18	
F20-17	90°	260	11.21	1.26	
F20-23	90°	260	10.70	1.18	
Avg.			10.68	1.17	
Std. Dev.			0.44	0.07	
F19-1	90°	350	11.12	1.09	4 pt. loading
F19-6	90°	350	9.68	1.02	
F20-10	90°	350	11.75	1.22	
F20-18	90°	350	12.80	1.16	
F20-25	90°	250	10.68	1.17	
Avg.			11.21	1.13	
Std. Dev.			1.31	0.08	

Test: Flexure				L/D Ratio: 32:1	
Materials: SIC/5506					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (ksi)	Modulus of Elasticity (10^6psi)	Remarks
G20-5	0°	-67	318.7	31.42	4 pt./tensile failure
G20-11	0°	-67	317.9	32.41	on lower surface
G20-16	0°	-67	333.3	31.42	
G20-20	0°	-67	318.7	32.42	
G20-24	0°	-67	324.7	31.72	
G20-28	0°	-67	336.4	33.14	
Avg.			324.9	31.92	
Std. Dev.			8.1	0.71	
G20-4	0°	72	316.3	32.04	4 pt./tensile failure
G20-8	0°	72	298.0	31.29	on lower surface
G20-17	0°	72	324.1	32.98	
G20-22	0°	72	313.5	31.35	
G20-23	0°	72	320.8	32.42	
Avg.			314.6	31.82	
Std. Dev.			10.1	0.48	
G20-7	0°	260	187.6	30.00	4 pt./shear failure
G20-14	0°	260	166.1	28.44	
G20-19	0°	260	171.4	29.61	
G20-21	0°	260	204.1	29.00	
G20-27	0°	260	217.2	30.89	
Avg.			189.3	29.59	Shear stress at
Std. Dev.			21.6	0.94	failure = 5900 psi

Test: Flexure				L/D Ratio: 32:1	
Materials: SiC/5506					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (ksi)	Modulus of Elasticity (10^6psi)	Remarks
G20-2	0°	350	109.9	32.22	4 pt/shear failure
F20-10	0°	350	118.0	29.11	
F20-13	0°	350	121.5	31.23	
F20-18	0°	350	124.7	31.42	
F20-26	0°	350	126.2	27.83	
Avg.			120.0	30.36	Shear stress at
Std.Dev.			6.5	1.82	failure = 3750 psi
G37-1	0°	260	322.6	28.87	3 pt/tensile failure
G37-3	0°	260	308.7	28.67	on lower surface
G37-5	0°	260	322.9	30.23	
G37-7	0°	260	312.4	28.07	
Avg.			316.7	28.96	
Std. Dev.			7.2	0.91	
G37-2	0°	350	170.1	24.00	3 pt/shear failure
G37-4	0°	350	182.9	25.70	
G37-6	0°	350	173.8	24.04	
G37-8	0°	350	175.2	24.56	
Avg.			175.5	24.58	Shear stress at
Std.Dev.			5.4	0.79	failure = 2770 psi
G21-3	90°	-67	17.3	2.85	4 pt. loading
G21-9	90°	-67	17.3	2.62	
G21-14	90°	-67	14.9	2.58	
G21-23	90°	-67	14.6	2.95	
G21-29	90°	-67	15.2	2.54	
Avg.			15.9	2.71	
Std.Dev.			1.3	0.18	

Test: Flexure				L/D Ratio: 32:1	
Materials: SIC/5506					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (ksi)	Modulus of Elasticity (10^6psi)	Remarks
G21-1	90°	72	14.9	2.52	4 pt. loading
G21-5	90°	72	15.5	2.44	
G21-10	90°	72	13.5	2.31	
G21-15	90°	72	15.0	2.23	
G21-20	90°	72	14.3	2.17	
G21-25	90°	72	13.9	2.39	
Avg.			14.5	2.34	
Std.Dev.			0.8	0.13	
G21-2	90°	260	10.0	1.18	4 pt. loading
G21-8	90°	260	10.3	1.57	
G21-16	90°	260	10.4	1.34	
G21-24	90°	260	11.6	1.50	
G21-28	90°	260	13.2	1.62	
Avg.			11.1	1.44	
Std.Dev.			1.4	0.18	
G21-4	90°	350	6.7	0.86	4 pt. loading
G21-6	90°	350	6.9	0.85	
G21-12	90°	350	7.7	0.89	
G21-21	90°	350	7.4	0.84	
G21-27	90°	350	6.1	0.82	
Avg.			7.0	0.85	
Std.Dev.			0.6	0.03	
G37-1	90°	350	8.2	0.93	3 pt. loading
G37-2	90°	350	11.3	1.13	
G37-3	90°	350	8.9	0.96	
G37-4	90°	350	11.1	1.12	
Avg.			9.9	1.03	
Std.Dev.			1.6	0.11	

Test: Flexure				L/D Ratio: 32:1	
Materials: HyE 2034D					
Specimen Number	Fiber Orientation	Test Temp. (°F)	Ultimate Strength (ksi)	Modulus of Elasticity (10^6psi)	Remarks
H8-5	0°	-67	96.1	37.92	4 pt. loading
H8-16	0°	-67	107.1	42.31	
H8-19	0°	-67	62.2	23.14	
H8-26	0°	-67	87.1	44.66	
H8-3	0°	-67	103.8	43.71	
H8-15	0°	-67	77.0	20.18	
Avg.			88.9	35.32	
Std.Dev.			17.1	10.87	
H8-10	0°	72	91.9	39.37	4 pt. loading
H8-13	0°	72	89.7	41.07	
H8-17	0°	72	91.9	41.62	
H8-21	0°	72	87.4	41.84	
H8-24	0°	72	90.2	43.87	
Avg.			90.2	41.55	
Std.Dev.			1.9	1.62	
H8-14	0°	260	65.9	41.40	4 pt. loading
H8-18	0°	260	68.7	41.80	
H8-20	0°	260	62.8	20.70	
H8-22	0°	260	69.0	44.01	
H8-23	0°	260	66.7	39.60	
Avg.			66.6	37.50	
Std.Dev.			2.5	9.52	
H8-4	0°	350	63.3	37.49	4 pt. loading
H8-6	0°	350	64.5	45.36	
H8-11	0°	350	66.7	39.16	
H8-12	0°	350	70.0	40.81	
H8-25	0°	350	69.9	39.47	
Avg.			66.9	40.46	
Std.Dev.			3.0	2.98	

Test: Flexure				L/D Ratio: 32:1	
Materials: HyE 2034D					
Specimen Number	Fiber Orientation	Test Temp. (°F)	Ultimate Strength (ksi)	Modulus of Elasticity (10^6psi)	Remarks
H9-1	90°	-67	5.54	1.04	4 pt. loading
H9-9	90°	-67	5.75	1.08	
H9-19	90°	-67	5.54	1.13	
H9-22	90°	-67	5.28	1.04	
H9-24	90°	-67	5.75	1.04	
Avg.			5.57	1.07	
Std. Dev.			0.19	0.04	
H9-3	90°	72	5.72	1.00	4 pt. loading
H9-6	90°	72	5.08	1.17	
H9-15	90°	72	5.57	1.08	
H9-16	90°	72	4.80	1.08	
H9-20	90°	72	5.31	1.12	
Avg.			5.30	1.09	
Std. Dev.			0.37	0.06	
H9-4	90°	260	3.78	0.91	4 pt. loading
H9-5	90°	260	3.78	0.87	
H9-8	90°	260	3.65	0.86	
H9-10	90°	260	3.38	0.91	
H9-11	90°	260	3.78	0.95	
Avg.			3.67	0.90	
Std. Dev.			0.17	0.04	
H9-12	90°	350	2.72	0.75	4 pt. loading
H9-7	90°	350	2.93	0.76	
H9-13	90°	350	2.65	0.80	
H9-14	90°	350	2.51	0.80	
H9-17	90°	350	3.20	0.76	
Avg.			2.80	0.77	
Std. Dev.			0.27	0.02	

Test: Flexure				L/D Ratio: 32:1	
Materials: T300/V378A					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (ksi)	Modulus of Elasticity (10^6psi)	Remarks
I1-6	0°	-67	289.4	17.08	3 pt/tensile failure
I1-13	0°	-67	276.3	16.13	on lower surface
I1-15	0°	-67	262.1	15.50	
I1-24	0°	-67	277.4	15.94	
I1-26	0°	-67	248.4	15.38	
Avg.			270.7	16.01	
Std.Dev.			15.8	0.67	
I1-5	0°	72	224.4	16.94	4 pt/mixed failure
I1-7	0°	72	232.3	15.81	modes. Some delamina-
I1-10	0°	72	220.1	19.19	tion; some tension on
I1-17	0°	72	219.5	16.94	lower surface; some
I1-23	0°	72	226.8	16.94	comp. under upper loading nose.
Avg.			224.6	17.16	Shear stress at
Std.Dev.			5.2	1.24	failure = 7010 psi.
I1-4	0°	350	166.6	16.89	4 pt/delamination fail
I1-11	0°	350	156.5	15.66	
Avg.			161.6	16.28	Shear stress at fail = 5040 psi
I1-16	0°	350	163.4	15.36	3 pt/mixed failure
I1-19	0°	350	175.4	16.32	modes. Some tension
I1-22	0°	350	172.8	15.18	on lower surface; some
Avg.			170.5	15.62	compression on upper
Std.Dev.			6.3	0.61	surface.

3 pt.

Test: Flexure				L/D Ratio: 32:1	
Materials: T300/V378A					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (ksi)	Modulus of Elasticity (10^6psi)	Remarks
I1-2	0°	450	172.8	16.67	tension on bottom &
I1-9	0°	450	176.1	16.23	compression on top
I1-12	0°	450	157.3	15.24	compressive failure
I1-14	0°	450	157.7	16.45	on upper surface
I1-21	0°	450	156.5	15.82	
Agv.			164.1	16.08	
Std.Dev.			9.5	0.57	

Test: Flexure				L/D Ratio: 32:1	
Materials: T300/V378A					
Specimen Number	Fiber Orientation	Test Temp. (°F)	Ultimate Strength (ksi)	Modulus of Elasticity (10^6psi)	Remarks
I2-2	90°	-67	10.40	1.81	4 pt. loading
I2-6	90°	-67	9.40	1.77	
I2-14	90°	-67	12.22	1.94	
I2-20	90°	-67	9.51	1.68	
I2-24	90°	-67	14.38	1.91	
Avg.			11.18	1.82	
Std.Dev.			2.12	0.11	
I2-1	90°	72	10.88	1.79	4 pt. loading
I2-7	90°	72	12.35	1.79	
I2-11	90°	72	12.14	1.74	
I2-18	90°	72	10.33	1.69	
I2-26	90°	72	12.20	1.68	
Avg.			11.58	1.74	
Std.Dev.			0.91	0.05	
I2-3	90°	350	6.92	1.37	4 pt. loading
I2-8	90°	350	7.45	1.49	
I2-15	90°	350	8.68	1.50	
I2-21	90°	350	9.80	1.53	
I2-25	90°	350	9.13	1.47	
Avg.			8.39	1.47	
Std.Dev.			1.19	0.06	
I2-4	90°	450	8.00	1.24	4 pt. loading
I2-12	90°	450	7.57	1.37	
I2-17	90°	450	8.52	1.28	
I2-19	90°	450	7.07	1.15	
I2-23	90°	450	8.03	1.38	
Avg.			7.84	1.29	
Std.Dev.			0.54	0.09	

Test: Flexure				L/D Ratio: 32:1	
Materials: HyE 1076J					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (ksi)	Modulus of Elasticity (10^6psi)	Remarks
J2-4	0°	-67	268.9	19.35	3 pt./tensile failure
J2-11	0°	-67	263.8	18.62	
J2-16	0°	-67	239.3	18.83	
J2-20	0°	-67	276.3	18.81	
J2-23	0°	-67	261.3	17.50	
Avg.			261.9	18.62	
Std. Dev.			13.9	0.68	
J2-2	0°	72	186.3	14.57	4 pt./tensile failure
J2-7	0°	72	189.7	13.84	
J2-9	0°	72	191.4	15.21	
J2-17	0°	72	187.5	15.37	
J2-22	0°	72	195.8	15.29	
Avg.			190.1	14.86	
Std. Dev.			3.6	0.65	
J2-5	0°	260	152.1	13.74	Note: primary failure
J2-8	0°	260	149.4	12.97	in compression(4 pt.)
J2-13	0°	260	148.1	12.02	
J2-18	0°	260	158.2	12.57	
J2-21	0°	260	176.2	13.97	tension failure/4 pt.
Avg.			156.8	13.05	
Std. Dev.			11.5	0.81	
J2-3	0°	350	145.7	17.08	shear failure/4 pt.
J2-10	0°	350	178.0	19.43	3 pt./compression fail.
J2-12	0°	350	183.3	19.07	
J2-15	0°	350	185.0	17.49	
J2-25	0°	350	197.4	17.31	
Avg.			185.9	18.32	Avg. omits J2-3
Std. Dev.			8.2	1.08	

Test: Flexure				L/D Ratio: 32:1	
Materials: HyE 1076J					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (ksi)	Modulus of Elasticity (10^6psi)	Remarks
J1-5	90°	-67	8.34	1.66	4 pt. loading
J1-10	90°	-67	9.21	1.58	
J1-15	90°	-67	11.78	1.98	
J1-19	90°	-67	10.48	2.01	
J1-25	90°	-67	11.73	1.98	
Avg.			10.31	1.84	
Std. Dev.			1.52	0.21	
J1-1	90°	72	8.58	1.64	4 pt. loading
J1-6	90°	72	7.38	1.57	
J1-12	90°	72	8.47	1.60	
J1-18	90°	72	10.66	1.91	
J1-24	90°	72	8.89	1.86	
Avg.			8.79	1.71	
Std. Dev.			1.19	0.16	
J1-4	90°	260	5.85	1.49	4 pt. loading
J1-8	90°	260	6.54	1.58	
J1-16	90°	260	7.04	1.72	
J1-20	90°	260	8.62	1.71	
J1-26	90°	260	9.06	1.60	
Avg.			7.42	1.62	
Std. Dev.			1.37	0.10	
J1-2	90°	350	6.53	1.35	4 pt. loading
J1-7	90°	350	6.31	1.40	
J1-14	90°	350	7.79	1.66	
J1-21	90°	350	8.66	1.58	
J1-23	90°	350	5.86	1.25	
Avg.			7.03	1.45	
Std. Dev.			1.16	0.17	

Test: Flexure				L/D Ratio: 32:1	
Materials: G-160/6535-1					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (10^3 psi)	Modulus of Elasticity (10^6psi)	Remarks
K41-4	0°	-67	243.4	18.62	3 pt. loading/tens.fail.
K41-9	0°	-67	236.3	17.70	
K41-21	0°	-67	251.6	19.09	
K41-23	0°	-67	212.3	18.85	
K41-29	0°	-67	255.9	20.94	
Avg.			239.9	19.04	
Std. Dev.			17.2	1.19	
K41-1	0°	72	237.6	18.34	4 pt. loading/tens. &
K41-5	0°	72	230.7	18.22	compr. failure
K41-10	0°	72	235.9	18.33	
K41-20	0°	72	215.2	20.09	
K41-15	0°	72	237.0	17.48	
Avg.			231.3	18.49	
Std. Dev.			9.4	0.96	
K41-3	0°	260	199.5	19.06	4 pt. load/shear fail.
K41-7	0°	260	128.0	19.40	4 pt. load/shear fail.
K41-11	0°	260	214.2	18.49	3 pt. load/tens. &
K41-16	0°	260	223.5	17.33	compr. failure
K41-25	0°	260	221.5	18.19	
Avg.			219.7	18.00	omits K41-3 & K41-7
Std. Dev.			4.9	0.60	omits K41-3 & K41-7
K41-2	0°	350	186.5	16.21	3 pt. load/tens. &
K41-6	0°	350	179.6	16.44	compr. failure
K41-12	0°	350	177.5	17.46	
K41-18	0°	350	189.4	17.53	
K41-22	0°	350	175.8	16.62	
Avg.			181.7	16.95	
Std. Dev.			5.9	0.61	

Test: Flexure				L/D Ratio: 32:1	
Materials: G-160/6535-1					
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Modulus of Elasticity (10^6psi)	Remarks
K42-9	90°	-67	10.14	1.58	4 pt. load
K42-15	90°	-67	10.11	1.52	
K42-21	90°	-67	7.09	1.50	
K42-3	90°	-67	8.59	1.83	
K42-23	90°	-67	8.63	2.16	
Avg.			9.11	1.53	
Std. Dev.			1.75	0.04	
K42-1	90°	72	8.41	1.39	4 pt. load
K42-13	90°	72	9.29	1.46	
K42-25	90°	72	8.90	1.50	
K42-7	90°	72	8.73	1.46	
K42-18	90°	72	8.64	1.41	
Avg.			8.86	1.45	
Std. Dev.			0.44	0.06	
K42-8	90°	260	6.65	1.48	4 pt. load
K42-20	90°	260	6.67	1.47	
K42-26	90°	260	5.86	1.41	
K42-4	90°	260	7.78	1.42	
K42-14	90°	260	4.70	1.22	
Avg.			6.40	1.45	
Std. Dev.			0.47	0.04	
K42-2	90°	350	6.32	1.26	4 pt. load
K42-19	90°	350	6.75	1.49	
K42-24	90°	350	6.45	1.26	
K42-6	90°	350	7.15	1.44	
K42-12	90°	350	7.56	1.33	
Avg.			6.50	1.34	
Std. Dev.			0.22	0.13	

APPENDIX G
INPLANE SHEAR DATA

All of the inplane shear data generated during this program are presented in this section. These data are both tabularly and graphically summarized in Sections 4.1 through 4.6.

Test: Inplane Shear						
Materials: T300/AFR800						
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Inplane Shear Modulus (10^6psi)	Ultimate Strain (in/in)	Remarks
F23-5	±45	-67	13,900	0.71		
F24-1	±45	-67	13,360	0.67		
F25-7	±45	-67	12,850	0.65		
F26-4	±45	-67	12,620	0.65		
F27-10	±45	-67	13,370	0.70		
Avg.			13,220	0.68		
Std.Dev.			500	0.03		
F23-9	±45	72	12,030	0.69		
F24-9	±45	72	11,900	0.72		
F25-5	±45	72	10,750	0.60		
F26-10	±45	72	11,850	0.66		
F27-1	±45	72	11,570	0.73		
Avg.			11,620	0.68		
Std.Dev.			520	0.05		
F23-11	±45	260	9,020	0.65		
F24-4	±45	260	7,720	0.59		
F25-1	±45	260	8,610	0.65		
F26-8	±45	260	8,730	0.60		
F27-3	±45	260	7,940	0.58		
Avg.			8,400	0.61		
Std.Dev.			550	0.03		
F23-3	±45	350	8,530	0.43		
F24-7	±45	350	8,180	0.45		
F25-10	±45	350	8,560	0.45		
F26-2	±45	350	7,670	0.40		
F27-5	±45	350	7,720	0.41		
Avg.			8,130	0.43		
Std.Dev.			430	0.02		

Test: Inplane Shear						
Materials: SiC/5506						
Specimen Number	Fiber Orientation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Inplane Shear Modulus (10^6psi)	Ultimate Strain (in/in)	Remarks
G14-3	±45°	-67	10.31	1.02		
G14-4	±45°	-67	10.12	1.06		
G15-2	±45°	-67	10.20	1.07		
G17-3	±45°	-67	8.85	1.12		
G17-6	±45°	-67	9.83	1.07		
Avg.			9.86	1.07		
Std.Dev.			0.59	---		
G14-5	±45°	72	8.85	0.76		
G15-1	±45°	72	8.26	0.87		
G15-4	±45°	72	8.76	0.76		
G17-1	±45°	72	8.97	0.88		
G17-4	±45°	72	8.46	0.73		
Avg.			8.66	0.80		
Std.Dev.			0.29	0.07		
G14-7	±45°	260	5.80	0.50		
G16-4	±45°	260	6.27	0.33		
G17-2	±45°	260	6.11	0.39		
G17-7	±45°	260	5.37	0.37		
G17-8	±45°	260	5.35	0.39		
Avg.			5.78	0.39		
Std. Dev.			0.42	0.06		
G14-1	±45°	350	3.97	0.12		
G14-2	±45°	350	3.93	0.11		
G14-6	±45°	350	3.94	0.18		
G15-3	±45°	350	4.09	0.11		
G17-5	±45°	350	3.84	0.10		
Avg.			3.95	0.12		
Std.Dev.			0.09	0.03		

Test: Inplane Shear						
Materials: HyE 2034D						
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Inplane Shear Modulus (10^6psi)	Ultimate Strain (in/in)	Remarks
H11-8	±45°	-67	5.83	0.99		
H16-4	±45°	-67	6.12	1.02		
H17-4	±45°	-67	5.81	1.02		
H17-7	±45°	-67	6.22	1.00		
H12-7	±45°	-67	5.67	1.31		
Avg.			5.93	1.07		
Std.Dev.			0.23	0.14		
H11-7	±45°	72	5.51	0.76		
H13-8	±45°	72	5.50	0.80		
H15-4	±45°	72	5.39	0.68		
H15-5	±45°	72	5.59	0.74		
H15-7	±45°	72	5.14	0.66		
Avg.			5.43	0.73		
Std.Dev.			0.17	0.06		
H10-2	±45°	260	4.68	0.68		
H12-13	±45°	260	4.70	0.68		
H13-1	±45°	260	4.88	0.66		
H14-10	±45°	260	4.48	0.63		
H17-6	±45°	260	4.47	0.66		
Avg.			4.69	0.66		
Std.Dev.			0.14	0.02		
H10-5	±45°	350	4.36	0.68		
H11-9	±45°	350	4.21	0.60		
H14-5	±45°	350	4.54	0.56		
H18-2	±45°	350	4.56	0.62		
H19-4	±45°	350	4.22	0.57		
Avg.			4.38	0.61		
Std.Dev.			0.17	0.04		

Test: Inplane Shear						
Materials: T300/V378A						
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Inplane Shear Modulus (10^6psi)	Ultimate Strain (in/in)	Remarks
I4-6	±45	-67	11.19	0.91		
I5-10	±45	-67	11.56	0.97		
I6-8	±45	-67	10.48	0.92		
I9-1	±45	-67	10.42	0.90		
I10-5	±45	-67	10.17	0.92		
Avg.			10.76	0.92		
Std.Dev.			0.59	0.03		
I4-3	±45	72	9.59	0.89		
I9-9	±45	72	11.07	0.95		
I10-7	±45	72	10.71	0.97		
I11-5	±45	72	10.98	0.91		
I22-1	±45	72	10.88	0.95		
Avg.			10.65	0.93		
Std.Dev.			0.61	0.03		
I8-6	±45	350	8.13	0.85		
I9-8	±45	350	8.09	0.88		
I10-10	±45	350	7.48	0.76		
I11-4	±45	350	8.39	0.95		
I22-2	±45	350	8.21	---		
Avg.			8.06	0.86		
Std.Dev.			0.35	0.08		
I5-1	±45	450	7.23	0.63		
I8-7	±45	450	7.46	0.69		
I9-6	±45	450	7.51	0.58		
I10-9	±45	450	7.44	0.54		
I11-8	±45	450	7.70	0.58		
Avg.			7.47	0.60		
Std.Dev.			0.17	0.06		

Test: Inplane Shear

Materials: HyE 1076J

Specimen Number	Fiber Orientation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Inplane Shear Modulus (10^6psi)	Ultimate Strain (in/in)	Remarks
J4-3	±45°	-67	13.39	0.99		
J6-2	±45°	-67	15.46	0.89		
J8-2	±45°	-67	13.20	1.08		
J10-2	±45°	-67	13.34	1.03		
J11-3	±45°	-67	13.34	1.03		
Avg.			13.75	1.00		
Std.Dev.			0.96	0.07		
J3-2	±45°	72	11.00	0.90		
J5-6	±45°	72	11.09	0.84		
J8-2	±45°	72	11.08	0.94		
J11-2	±45°	72	11.36	0.93		
J12-2	±45°	72	11.17	0.96		
Avg.			11.14	0.92		
Std.Dev.			0.14	0.05		
J3-1	±45°	260	7.78	0.87		
J5-1	±45°	260	7.90	0.90		
J7-1	±45°	260	8.72	0.92		
J9-1	±45°	260	8.45	0.94		
J11-1	±45°	260	8.38	0.82		
Avg.			8.25	0.89		
Std.Dev.			0.40	0.05		
J3-6	±45°	350	8.36	0.79		
J4-2	±45°	350	8.18	0.81		
J7-6	±45°	350	9.36	0.70		
J9-7	±45°	350	7.67	0.82		
J11-8	±45°	350	7.93	0.71		
Avg.			8.30	0.77		
Std.Dev.			0.65	0.06		

Test: Inplane Shear						
Materials: G-160/6535-1						
Specimen Number	Fiber Orien-tation	Test Temp. (°F)	Ultimate Strength (10^3psi)	Inplane Shear Modulus (10^6psi)	Ultimate Strain (in/in)	Remarks
K4-4	±45°	-67	9.34	1.03		
K6-2	±45°	-67	9.85	0.97		
K7-4	±45°	-67	10.44	0.96		
K10-3	±45°	-67	9.44	1.01		
K11-1	±45°	-67	9.47	1.10		
Avg.			9.71	1.01		
Std.Dev.			0.45	0.06		
K5-1	±45°	72	8.87	0.94		
K6-1	±45°	72	9.00	0.96		
K7-1	±45°	72	7.68	0.98		
K8-1	±45°	72	8.90	0.90		
K9-1	±45°	72	7.72	0.94		
Avg.			8.43	0.94		
Std.Dev.			0.67	0.03		
K4-2	±45°	260	7.74	0.82		
K5-2	±45°	260	7.90	0.96		
K7-2	±45°	260	7.94	0.89		
K9-2	±45°	260	7.86	0.87		
K10-2	±45°	260	7.42	0.89		
Avg.			7.77	0.89		
Std.Dev.			0.21	0.05		
K4-3	±45°	350	7.76	0.79		
K5-3	±45°	350	8.74	0.84		
K7-3	±45°	350	8.66	0.86		
K9-3	±45°	350	8.50	0.80		
K10-2	±45°	350	7.54	0.78		
Avg.			8.24	0.81		
Std.Dev.			0.55	0.03		

APPENDIX H
INTERLAMINAR SHEAR DATA

All of the interlaminar shear data generated during this program are tabulated in this appendix. Tabular summaries of these data appear in Sections 4.1 through 4.6.

Test: Interlaminar (Short-Beam) Shear			
Materials: T300/AFR800			L/D Ratio: 4/1
Specimen Number	Test Temp. (°F)	Ultimate Strength (psi)	Remarks
F21-23	-67	19,020	
F21-45	-67	17,550	
F21-55	-67	17,700	
F21-58	-67	17,270	
F21-61	-67	19,290	
Avg.		18,170	
Std.Dev.		920	
F21-6	72	15,290	
F21-9	72	15,520	
F21-11	72	17,160	
F21-20	72	14,440	
F21-36	72	15,310	
F21-53	72	15,340	
F21-64	72	14,370	
F21-66	72	14,620	
F21-69	72	15,400	
F21-75	72	15,160	
Avg.		15,270	
Std.Dev.		790	
F21-33	260	12,810	
F21-43	260	11,020	
F21-44	260	11,920	
F21-57	260	11,300	
F21-68	260	11,820	
Avg.		11,770	
Std. Dev.		690	

Test: Interlaminar (Short-Beam) Shear			
Materials: T300/AFR800		L/D Ratio: 4/1	
Specimen Number	Test Temp. (°F)	Ultimate Strength (psi)	Remarks
F21-7	350	9,880	
F21-12	350	9,270	
F21-26	350	10,000	
F21-51	350	9,320	
F21-56	350	9,680	
Avg.		9,630	
Std.Dev.		330	

Test: Interlaminar (Short-Beam) Shear			
Materials: SiC/5506			L/D Ratio: 4/1
Specimen Number	Test Temp. (°F)	Ultimate Strength (10^3 psi)	Remarks
G38-6	-67	21.27	
G38-28	-67	21.68	
G38-51	-67	21.32	
G38-57	-67	21.06	
G38-63	-67	21.10	
Avg.		21.29	
Std.Dev.		0.25	
G38-2	72	14.80	
G38-4	72	14.85	
G38-8	72	14.96	
G38-12	72	15.01	
G38-20	72	15.21	
G38-24	72	14.72	
G38-30	72	14.96	
G38-36	72	15.20	
G38-40	72	15.19	
G38-48	72	15.31	
Avg.		15.02	
Std.Dev.		0.20	
G38-1	260	8.81	
G38-16	260	9.55	
G38-39	260	8.86	
G38-41	260	9.20	
G38-54	260	9.18	
Avg.		9.12	
Std.Dev.		0.30	

Test: Interlaminar (Short-Beam) Shear			
Materials: SiC/5506		L/D Ratio: 4/1	
Specimen Number	Test Temp. (°F)	Ultimate Strength (10^3 psi)	Remarks
G38-17	350	7.53	
G38-25	350	8.01	
G38-33	350	8.59	
G38-44	350	8.11	
G38-60	350	7.83	
Avg.		8.01	
Std.Dev.		0.39	

Test: Interlaminar (Short-Beam) Shear			
Materials: HyE 2034D		L/D Ratio: 4/1	
Specimen Number	Test Temp. (°F)	Ultimate Strength (10^3 psi)	Remarks
H31-2	-67	9.06	
H31-7	-67	7.83	
H31-16	-67	8.14	
H31-44	-67	7.91	
H31-54	-67	7.51	
Avg.		8.09	
Std.Dev.		0.59	
H31-1	72	7.57	
H31-5	72	7.17	
H31-10	72	7.07	
H31-22	72	7.85	
H31-36	72	7.06	
H31-42	72	7.57	
H31-48	72	7.57	
H31-51	72	6.55	
H31-55	72	6.97	
H31-66	72	6.45	
Avg.		7.18	
Std.Dev.		0.46	
H31-3	260	7.12	
H31-8	260	6.24	
H31-28	260	6.13	
H31-30	260	6.04	
H31-46	260	6.87	
Avg.		6.48	
Std.Dev.		0.48	

Test: Interlaminar (Short-Beam) Shear			
Materials: HyE 2034D			L/D Ratio: 4/1
Specimen Number	Test Temp. (°F)	Ultimate Strength (10^3 psi)	Remarks
H31-17	350	6.17	
H31-24	350	5.82	
H31-40	350	5.95	
H31-53	350	5.74	
H31-64	350	5.48	
Avg.		5.83	
Std.Dev.		0.26	

Test: Interlaminar (Short-Beam) Shear			
Materials: T300/V378A			L/D Ratio: 4/1
Specimen Number	Test Temp. (°F)	Ultimate Strength (psi)	Remarks
I15-9	-67	18,800	
I15-14	-67	17,300	
I15-26	-67	18,540	
I15-38	-67	18,250	
I15-39	-67	17,720	
Avg.		18,140	
Std.Dev.		630	
I15-1	72	15,400	
I15-4	72	15,560	
I15-8	72	14,860	
I15-13	72	14,230	
I15-20	72	14,520	
I15-25	72	15,550	
I15-29	72	15,160	
I15-32	72	15,170	
I15-37	72	14,410	
I15-45	72	15,320	
Avg.		15,020	
Std.Dev.		490	
I15-10	350	9,030	
I15-16	350	10,090	
I15-24	350	10,190	
I15-27	350	10,760	
I15-34	350	10,010	
Avg.		10,020	
Std.Dev.		620	

Test: Interlaminar (Short-Beam) Shear			
Materials: T300/V378A			L/D Ratio: 4/1
Specimen Number	Test Temp. (°F)	Ultimate Strength (psi)	Remarks
I15-2	450	8,960	
I15-6	450	9,230	
I15-17	450	9,430	
I15-28	450	9,270	
I15-43	450	9,310	
Avg.		9,240	
Std.Dev.		170	

Test: Interlaminar (Short-Beam) Shear			
Materials: HyE 1076J			L/D Ratio: 4/1
Specimen Number	Test Temp. (°F)	Ultimate Strength (10^3 psi)	Remarks
J26-23	-67	16.26	
J26-41	-67	14.24	
J26-67	-67	19.64	
J26-78	-67	15.25	
J26-80	-67	17.72	
Avg.		16.62	
Std.Dev.		2.12	
J26-16	72	11.04	
J26-19	72	9.42	
J26-26	72	10.96	
J26-33	72	14.94	
J26-40	72	11.67	
J26-49	72	12.66	
J26-53	72	11.67	
J26-69	72	17.11	
J26-74	72	14.70	
J26-83	72	14.56	
Avg.		12.87	
Std.Dev.		2.36	
J26-18	260	8.59	
J26-34	260	10.79	
J26-38	260	8.96	
J26-52	260	8.61	
J26-64	260	9.85	
Avg.		9.36	
Std.Dev.		0.95	

Test: Interlaminar (Short-Beam) Shear			
Materials: HyE 1076J		L/D Ratio: 4/1	
Specimen Number	Test Temp. (°F)	Ultimate Strength (10^3 psi)	Remarks
J26-14	350	7.71	
J26-22	350	8.89	
J26-46	350	8.58	
J26-57	350	9.56	
J26-61	350	8.25	
Avg.		8.60	
Std.Dev.		0.69	

Test: Interlaminar (Short-Beam) Shear			
Materials: G-160/6535-1			L/D Ratio: 4/1
Specimen Number	Test Temp. (°F)	Ultimate Strength (10^3psi)	Remarks
K18-12	-67	17.51	
K18-28	-67	18.21	
K18-38	-67	15.19	
K18-46	-67	16.65	
K18-62	-67	17.20	
Avg.		16.96	
Std. Dev.		1.14	
K18-1	72	14.03	
K18-10	72	15.55	
K18-18	72	15.87	
K18-23	72	14.21	
K18-31	72	13.10	
K18-34	72	14.26	
K18-37	72	12.84	
K18-41	72	13.79	
K18-47	72	16.13	
K18-52	72	15.54	
Avg.		14.53	
Std. Dev.		1.17	
K18-2	260	11.36	
K18-16	260	11.46	
K18-48	260	12.39	
K18-57	260	12.28	
K18-63	260	12.02	
Avg.		11.90	
Std. Dev.		0.47	

Test: Interlaminar (Short-Beam) Shear			
Materials: G-160/6535-1			L/D Ratio: 4/1
Specimen Number	Test Temp. (°F)	Ultimate Strength (10^3psi)	Remarks
K18-9	350	8.76	
K18-26	350	9.53	
K18-35	350	8.46	
K18-44	350	9.79	
K18-55	350	9.78	
Avg.		9.27	
Std. Dev.		0.62	

APPENDIX I
FATIGUE DATA

All of the tensile-tensile fatigue data generated during the program, along with residual strengths of specimens which "ran out" to 10^7 cycles are presented here. The residual strengths were all determined with a tensile test at 72°F (22°C), regardless of what temperature the specimen saw during the fatigue test. Summaries of these data are presented in Sections 4.1 through 4.6 in both tabular and graphical form.

Test: Tensile-Tensile Fatigue

Material: T300/AFR800

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
F1-2	0°	72	143.7	14.4	80	327,700	---	---	
F1-4	0°	72	143.7	14.4	80	23,600	---	---	
F1-10	0°	72	143.7	14.4	80	51,200	---	---	
F3-5	0°	72	143.7	14.4	80	1,400	---	---	
F3-6	0°	72	143.7	14.4	80	345,500	---	---	
F5-6	0°	72	134.7	13.5	75	10,000,000+	---	229.9	
F6-4	0°	72	134.7	13.5	75	168,200	---	---	
F6-12	0°	72	134.7	13.5	75	2,294,900	---	---	
F22-3	0°	72	134.7	13.5	75	10,000,000+	---	151.3	
F22-5	0°	72	134.7	13.5	75	10,000,000+	---	239.7	
F22-11	0°	72	134.7	13.5	75	10,000,000+	---	223.3	
F3-12	0°	72	125.7	12.6	70	7,800	---	---	
F4-4	0°	72	125.7	12.6	70	10,000,000+	---	201.7	
F4-5	0°	72	125.7	12.6	70	10,000,000+	---	198.8	
F5-1	0°	72	125.7	12.6	70	10,000,000+	---	209.3	
F6-7	0°	72	125.7	12.6	70	1,999,400	+5	---	
F22-10	0°	72	125.7	12.6	70	5,888,600	---	---	failed by operator error

Test: Tensile-Tensile Fatigue — R = +0.1

Material: T300/AFR200 — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
F4-13	0°	260	174.5	17.5	90	700	---	---	
F5-15	0°	260	174.5	17.5	90	197,200	+8	---	
F6-16	0°	260	174.5	17.5	90	1,000	---	---	
F22-7	0°	260	174.5	17.5	90	1,500	+3	---	
F22-10	0°	260	174.5	17.5	90	163,500	+16	---	
F4-10	0°	260	155.1	15.5	80	116,500	+5	---	
F5-8	0°	260	155.1	15.5	80	12,800	+7	---	
F6-1	0°	260	155.1	15.5	80	6,900	+9	---	
F22-2	0°	260	155.1	15.5	80	806,600	+8	---	
F22-13	0°	260	155.1	15.5	80	5,622,100	+6	---	
F5-14	0°	260	145.4	14.5	75	7,185,700	---	---	overheated to 400°F
F6-14	0°	260	145.4	14.5	75	56,500	+6	---	
F22-4	0°	260	145.4	14.5	75	3,531,600	+3	---	
F22-6	0°	260	145.4	14.5	75	4,806,800	+3	---	
F22-14	0°	260	145.4	14.5	75	10,000,000+	+1	187.6	

Test: Tensile-Tensile Fatigue

Material: T300/AFR800

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
F7-4	90°	72	3.66	0.37	80	700	---	---	didn't reach full load
F7-1	90°	72	3.66	0.37	80	200	---	---	before failure
F11-4	90°	72	3.66	0.37	80	200	---	---	↓
F13-3	90°	72	3.21	0.32	70	30,200	---	---	
F14-4	90°	72	3.21	0.32	70	602,300	---	---	
F16-8	90°	72	3.21	0.32	70	1,111,300	---	---	
F17-1	90°	72	3.21	0.32	70	43,700	---	---	
F17-5	90°	72	3.21	0.32	70	56,200	---	---	
F17-10	90°	72	3.21	0.32	70	400	---	---	
F15-3	90°	72	2.98	0.30	65	22,600	---	---	
F16-4	90°	72	2.98	0.30	65	19,700	---	---	
F17-4	90°	72	2.98	0.30	65	2,100	---	---	
F18-2	90°	72	2.98	0.30	65	151,100	---	---	
F18-9	90°	72	2.98	0.30	65	147,500	---	---	
F9-2	90°	72	2.75	0.28	60	10,000,000+	---	6.4	
F11-8	90°	72	2.75	0.28	60	2,994,700	---	---	
F13-1	90°	72	2.75	0.28	60	22,700	---	---	
F13-8	90°	72	2.75	0.28	60	314,900	---	---	
F13-10	90°	72	2.75	0.28	60	10,000,000+	---	4.6	

Test: Tensile-Tensile Fatigue

Material: T300/AFR800

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
F12-3	90°	260	3.28	0.33	70	400	---	---	
F14-8	90°	260	2.98	0.30	65	18,800	0	---	
F17-7	90°	260	2.98	0.30	65	3,300	+1	---	
F18-4	90°	260	2.98	0.30	65	10,700	0	---	
F13-2	90°	260	2.81	0.28	60	500	+2	---	
F14-2	90°	260	2.81	0.28	60	25,400	0	---	
F14-7	90°	260	2.81	0.28	60	400	+1	---	
F16-2	90°	260	2.81	0.28	60	7,207,000	3	---	
F18-10	90°	260	2.81	0.28	60	10,000,000+	+1	7.3	
F18-7	90°	260	2.57	0.26	55	10,000,000+	1	6.1	
F18-1	90°	260	2.34	0.23	50	10,000,000+	1	6.4	

Test: Tensile-Tensile Fatigue

Material: T300/AFR800

R = +0.1

Frequency = .30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
F23-1	±45°	72	16.27	1.63	70	13,300	---	---	
F23-7	±45°	72	16.27	1.63	70	19,700	---	---	
F23-8	±45°	72	16.27	1.63	70	29,000	---	---	
F23-10	±45°	72	16.27	1.63	70	21,700	---	---	
F24-11	±45°	72	16.27	1.63	70	10,500	---	---	
F26-1	±45°	72	15.11	1.51	65	36,800	+6	---	
F27-11	±45°	72	15.11	1.51	65	48,500	+6	---	
F28-3	±45°	72	15.11	1.51	65	12,900	+7	---	
F30-1	±45°	72	15.11	1.51	65	68,700	+7	---	
F33-1	±45°	72	15.11	1.51	65	154,500	+5	---	
F25-9	±45°	72	13.94	1.39	60	1,199,300	+11	---	
F30-4	±45°	72	13.94	1.39	60	146,100	+12	---	
F32-7	±45°	72	13.94	1.39	60	3,985,200	+7	---	
F32-11	±45°	72	13.94	1.39	60	1,654,000	+7	---	
F33-4	±45°	72	13.94	1.39	60	4,719,900	+7	---	

Test: Tensile-Tensile Fatigue

Material: T300/AFR800

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
F30-5	±45°	260	12.60	1.26	75	51,800	+12	---	
F32-5	±45°	260	12.60	1.26	75	108,900	+8	---	
F32-9	±45°	260	12.60	1.26	75	71,500	+4	---	
F33-3	±45°	260	12.60	1.26	75	80,700	+9	---	
F33-5	±45°	260	12.60	1.26	75	129,100	+2	---	
F24-10	±45°	260	11.76	1.18	70	42,400	+10	---	
F25-4	±45°	260	11.76	1.18	70	34,900	+13	---	
F25-8	±45°	260	11.76	1.18	70	51,900	+4	---	
F32-1	±45°	260	11.76	1.18	70	4,900	+6	---	
F33-8	±45°	260	11.76	1.18	70	4,011,700	+3	---	
F27-4	±45°	260	10.92	1.09	65	2,006,000	+1	---	
F27-8	±45°	260	10.92	1.09	65	1,571,300	+7	---	
F28-7	±45°	260	10.92	1.09	65	3,158,900	+1	---	
F32-4	±45°	260	10.92	1.09	65	4,883,200	0	---	
F32-10	±45°	260	10.92	1.09	65	10,049,800	+3	21.2	

Test: Tensile-Tensile Fatigue

Material: SiC/5506

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
G27-4	±45°	72	7.79	0.78	45	5,840,400	+7	---	
G29-8	±45°	72	7.79	0.78	45	1,603,100	+8	---	
G30-8	±45°	72	7.79	0.78	45	1,389,600	+16	---	
G31-2	±45°	72	7.79	0.78	45	3,870,200	+7	---	
G27-6	±45°	72	9.53	0.95	55	83,000	+7	---	
G28-2	±45°	72	9.53	0.95	55	100,300	+17	---	
G30-3	±45°	72	9.53	0.95	55	96,100	+5	---	
G31-7	±45°	72	9.53	0.95	55	101,700	+6	---	
G30-7	±45°	72	10.39	1.04	60	24,300	+9	---	
G14-8	±45°	72	12.12	1.21	70	2,600	+14	---	
G15-6	±45°	72	12.12	1.21	70	4,700	+12	---	
G15-8	±45°	72	12.12	1.21	70	4,700	+16	---	
G16-2	±45°	72	12.12	1.21	70	2,000	+13	---	
G30-5	±45°	72	12.12	1.21	70	4,800	+15	---	

Test: Tensile-Tensile Fatigue

Material: SiC/5506

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
G28-9	±45°	260	5.18	0.52	45	3,763,700	---	---	failed by operator error
G29-6	±45°	260	5.18	0.52	45	10,000,000+	+3	1[illegible].23	
G28-6	±45°	260	5.76	0.58	50	10,000,000+	+3	14.62	
G27-1	±45°	260	6.34	0.63	55	70,100	+26	---	
G28-1	±45°	260	6.34	0.63	55	113,600	+29	---	
G29-4	±45°	260	6.34	0.63	55	44,300	+16	---	
G31-4	±45°	260	6.34	0.63	55	93,300	+6	---	
G31-3	±45°	260	6.91	0.69	60	11,600	+18	---	
G15-5	±45°	260	8.06	0.81	70	9,400	+19	---	
G15-7	±45°	260	8.06	0.81	70	3,200	+25	---	
G16-1	±45°	260	8.06	0.81	70	2,300	+26	---	
G16-3	±45°	260	8.06	0.81	70	2,200	+27	---	
G30-6	±45°	260	8.06	0.31	70	2,800	+23	---	

Test: Tensile-Tensile Fatigue $R = +0.1$

Material: SiC/5506 Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation *	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
G32-6	0/±45/90	72	59.6	5.96	50%	2,557,000	+19	---	
G33-6	0/±45/90	72	59.6	5.96	50%	6,650,560	+27	---	
G40-7	0/±45/90	72	59.6	5.96	50%	2,396,300	+30	---	
G41-4	0/±45/90	72	59.6	5.96	50%	3,060,200	+10	---	
G44-4	0/±45/90	72	59.6	5.96	50%	3,995,200	+35	---	
G32-1	0/±45/90	72	65.6	6.56	55%	482,300	+20	---	
G34-2	0/±45/90	72	65.6	6.56	55%	811,000	+39	---	
G40-3	0/±45/90	72	65.6	6.56	55%	1,700,900	+17	---	
G34-5	0/±45/90	72	77.5	7.75	65%	29,400	+31	---	
G39-8	0/±45/90	72	77.5	7.75	65%	27,600	+27	---	
G44-8	0/±45/90	72	77.5	7.75	65%	106,800	+25	---	

* $(0, +45, -45, 0, 0, -45, +45, 0, 90, 0)_s$ - 20 ply

Test: Tensile-Tensile Fatigue

Material: SiC/5506

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation *	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
G32-9	0/±45/90	260	58.6	5.86	50%	413,200	+12	---	
G39-1	0/±45/90	260	58.6	5.86	50%	612,600	+16	---	
G41-7	0/±45/90	260	58.6	5.86	50%	48,900	+2	---	
G44-7	0/±45/90	260	58.6	5.86	50%	1,148,400	+13	---	
G33-3	0/±45/90	260	64.5	6.45	55%	98,200	+1	---	
G35-4	0/±45/90	260	64.5	6.45	55%	140,800	+20	---	
G40-1	0/±45/90	260	64.5	6.45	55%	474,500	+18	---	
G32-4	0/±45/90	260	70.3	7.03	60%	5,700	+5	---	
G34-7	0/±45/90	260	70.3	7.03	60%	3,400	0	---	
G35-7	0/±45/90	260	70.3	7.03	60%	3,900	+16	---	
G40-9	0/±45/90	260	70.3	7.03	60%	5,500	+15	---	

* (0, +45, -45, 0, 0, -45, +45, 0, 90, $0)_s$ - 20 ply

Test: Tensile-Tensile Fatigue — R = +0.1

Material: SiC/5506 — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation *	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
G33-1	0/±45/90	72	62.5	6.25	75%	1,664,200	+14	---	
G34-4	0/±45/90	72	62.5	6.25	75%	1,571,100	+55	---	
G41-3	0/±45/90	72	62.5	6.25	75%	3,623,200	+30	---	
G39-6	0/±45/90	72	62.5	6.25	75%	1,363,200	+35	---	
G33-5	0/±45/90	72	75.0	7.50	90%	645,300	+56	---	
G35-9	0/±45/90	72	75.0	7.50	90%	30,100	+60	---	
G39-2	0/±45/90	72	75.0	7.50	90%	149,700	+61	---	
G41-1	0/±45/90	72	75.0	7.50	90%	133,900	+50	---	
G43-7	0/±45/90	72	75.0	7.50	90%	50,500	+82	---	
G32-3	0/±45/90	72	83.3	8.33	100%	36,200	+68	---	
G34-6	0/±45/90	72	83.3	8.33	100%	7,300	+28	---	
G40-6	0/±45/90	72	83.3	8.33	100%	17,300	+43	---	

Note: All these specimens had a 0.1935 inch (0.491 cm) hole in the center of the test section. Stresses were calculated using net cross-sectional area.

* $(0, +45, -45, 0, 0, -45, +45, 0, 90, 0)_s$ - 20 ply

Test: Tensile-Tensile Fatigue　　　　R = +0.1

Material: HyE 2034D　　　　Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
H17-1	±45°	72	6.51	0.65	60	3,543,500	2	---	
H14-3	±45°	72	6.51	0.65	60	10,000,000	2	10.33	
H13-5	±45°	72	6.51	0.65	60	10,000,000	2	9.71	
H10-1	±45°	72	6.51	0.65	60	10,000,000	3	9.36	
H19-2	±45°	72	8.14	0.81	75	69,500	6	---	
H16-1	±45°	72	8.14	0.81	75	39,300	4	---	
H14-1	±45°	72	8.14	0.81	75	47,300	3	---	
H13-2	±45°	72	8.14	0.81	75	150,900	4	---	
H11-1	±45°	72	8.14	0.81	75	107,300	10	---	
H18-9	±45°	72	8.68	0.87	80	64,200	3	---	
H15-3	±45°	72	8.68	0.87	80	58,000	4	---	
H13-7	±45°	72	8.68	0.87	80	13,800	3	---	
H12-2	±45°	72	8.68	0.87	80	2,700	3	---	
H10-10	±45°	72	8.68	0.87	80	43,500	7	---	
H19-3	±45°	260	6.10	0.61	65	7,767,200	0	---	
H16-2	±45°	260	6.57	0.66	70	88,300	3	---	
H14-2	±45°	260	6.57	0.66	70	1,543,000	5	---	
H13-3	±45°	260	6.57	0.66	70	1,372,400	7	---	
H11-4	±45°	260	6.57	0.66	70	5,089,600	2	---	

Test: Tensile-Tensile Fatigue									R = +0.1
Material: HyE 2034D									Frequency = 30 Hz
									Function: Sine
Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
H18-10	±45°	260	7.04	0.70	75	117,200	4	---	
H15-1	±45°	260	7.04	0.70	75	316,600	2	---	
H13-6	±45°	260	7.04	0.70	75	98,700	8	---	
H12-1	±45°	260	7.04	0.70	75	113,700	4	---	
H10-3	±45°	260	7.04	0.70	75	97,800	5	---	
H19-1	±45°	260	7.98	0.80	85	2,300	2	---	
H15-8	±45°	260	7.98	0.80	85	3,100	4	---	
H13-10	±45°	260	7.98	0.80	85	6,100	6	---	
H12-6	±45°	260	7.98	0.80	85	3,500	5	---	
H11-2	±45°	260	7.98	0.80	85	5,700	7	---	
H22-8	0/±45/90'	72	73.92	7.39	97.5	800	3	---	
H23-8	0/±45/90'	72	73.92	7.39	97.5	467,600	3	---	
H28-10	0/±45/90'	72	73.92	7.39	97.5	4,200	9	---	
H25-5	0/±45/90'	72	72.03	7.20	95	13,600	5	---	
H26-8	0/±45/90'	72	72.03	7.20	95	500	0	---	
H27-7	0/±45/90'	72	72.03	7.20	95	10,000,000+	8	78.78	
H21-9	0/±45/90'	72	72.03	7.20	95	12,000	10	---	
H33-4	0/±45/90'	72	72.03	7.20	95	10,000,000+	5	79.68	
H21-7	0/±45/90'	72	75.82	7.58	100	15,900	9	---	
H22-5	0/±45/90'	72	75.82	7.58	100	300	1	---	
H23-2	0/±45/90'	72	75.82	7.58	100	1,200	1	---	
H24-9	0/±45/90'	72	75.82	7.58	100	1,058,200	6	---	
H24-4	0/±45/90'	72	75.82	7.58	100	7,638,000	5	---	

$(0, +45, -45, 0, 0, -45, +45, 0, 90, 0)_s$ - 20 ply

Test: Tensile-Tensile Fatigue — R = +0.1

Material: HyE 2034D — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
H20-5	0/±45/90[1]	72	68.24	6.82	90	10,000,000+	3	76.50	
H27-5	0/±45/90[1,2]	72	38.83	3.88	60	10,000,000+	1	61.34	
H26-1	0/±45/90[1,2]	72	45.30	4.53	70	10,000,000+	2	59.93	
H24-3	0/±45/90[1,2]	72	51.78	5.18	80	10,000,000+	2	66.06	
H23-1	0/±45/90[1,2]	72	55.01	5.50	85	<100	---	---	

[1] $(0, +45, -45, 0, 0, -45, +45, 0, 90, 0)_s$ - 20 ply

[2] These specimens had a 0.1935 inch (0.491 cm) hole in center of test section. Stresses based on net cross-sectional area.

Test: Tensile-Tensile Fatigue | R = +0.1

Material: HyE 2034D | Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
H27-10	0/±45/90	72	58.25	5.83	90	4,393,600	4	---	
H25-6	0/±45/90	72	58.25	5.83	90	10,000,000+	2	70.42	
H24-5	0/±45/90	72	58.25	5.83	90	9,777,900+	1	---	failed by operator error
H23-10	0/±45/90	72	60.00	6.00	92.7	800	1	---	
H22-7	0/±45/90	72	60.00	6.00	92.7	10,000,000	0	67.22	
H28-3	0/±45/90	72	60.00	6.00	92.7	1,000	0	---	
H26-5	0/±45/90	72	61.48	6.15	95	568,400	4	---	
H22-3	0/±45/90	72	61.48	6.15	95	400	0	---	
H28-7	0/±45/90	72	61.48	6.15	95	600	0	---	
H25-7	0/±45/90	72	64.72	6.47	100	500	3	---	

Test: Tensile-Tensile Fatigue — R = +0.1

Material: T300/V378A — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
I3-6	±45°	72	15.97	1.60	75	31,000	8	---	
I7-2	±45°	72	15.97	1.60	75	24,200	9	---	
I10-3	±45°	72	15.97	1.60	75	9,100	7	---	
I11-6	±45°	72	15.97	1.60	75	20,500	8	---	
I22-6	±45°	72	15.97	1.60	75	9,400	9	---	
I3-2	±45°	72	14.90	1.49	70	47,600	6	---	
I7-3	±45°	72	14.90	1.49	70	92,700	6	---	
I10-6	±45°	72	14.90	1.49	70	61,600	6	---	
I11-2	±45°	72	14.90	1.49	70	82,700	6	---	
I3-9	±45°	72	13.84	1.38	65	582,500	5	---	
I7-6	±45°	72	13.84	1.38	65	269,900	4	---	
I10-2	±45°	72	13.84	1.38	65	210,000	8	---	
I11-3	±45°	72	13.84	1.38	65	433,000	5	---	
I22-4	±45°	72	13.84	1.38	65	1,020,700	6	---	
I3-8	±45°	350	13.70	1.37	85	9,400	14	---	
I6-1	±45°	350	13.70	1.37	85	3,900	19	---	
I7-1	±45°	350	13.70	1.37	85	500	5	---	
I10-8	±45°	350	13.70	1.37	85	10,300	15	---	
I22-3	±45°	350	13.70	1.37	85	12,500	13	---	
I6-7	±45°	350	12.90	1.29	80	59,300	9	---	
I10-1	±45°	350	12.90	1.29	80	50,500	6	---	
I11-1	±45°	350	12.90	1.29	80	43,100	5	---	
I22-8	±45°	350	12.90	1.29	80	56,700	9	---	

Test: Tensile-Tensile Fatigue | **R = +0.1**

Material: T300/V378A | **Frequency = 30 Hz**

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
I3-5	$\pm 45^\circ$	350	12.09	1.21	75	238,300	11	---	
I7-5	$\pm 45^\circ$	350	12.09	1.21	75	276,400	8	---	
I10-4	$\pm 45^\circ$	350	12.09	1.21	75	383,000	6	---	
I11-7	$\pm 45^\circ$	350	12.09	1.21	75	565,600	8	---	
I22-7	$\pm 45^\circ$	350	12.09	1.21	75	354,600	9	---	
I12-7	$0/\pm 45/90$[1]	72	95.78	9.58	80	1,800	32	---	
I35-4	$0/\pm 45/90$[1]	72	95.78	9.58	80	4,481,000	41	---	
I36-5	$0/\pm 45/90$[1]	72	95.78	9.58	80	3,000	35	---	
I33-7	$0/\pm 45/90$[1]	72	95.78	9.58	80	53,400	33	---	
I35-5	$0/\pm 45/90$[1]	72	92.78	9.28	77.5	1,300	8	---	
I37-6	$0/\pm 45/90$[1]	72	92.78	9.28	77.5	3,269,500	20	---	Failed due to power outage
I39-7	$0/\pm 45/90$[1]	72	92.78	9.28	77.5	99,600	30	---	
I40-7	$0/\pm 45/90$[1]	72	92.78	9.28	77.5	10,000,000+	25	104.36	
I25-6	$0/\pm 45/90$[1]	72	89.79	8.98	75	3,190,200	33	---	
I36-4	$0/\pm 45/90$[1]	72	89.79	8.98	75	10,000,000+	13	122.65	
I37-7	$0/\pm 45/90$[1]	72	89.79	8.98	75	3,985,800	55	---	
I13-7	$0/\pm 45/90$[1]	72	83.80	8.38	70	3,632,600	21	---	
I29-7	$0/\pm 45/90$[1]	72	83.80	8.38	70	10,000,000+	25	114.20	

[1] $(0, +45, -45, 0, 0, -45, +45, 0, 90, 0)_s$ - 20 ply

Test: Tensile-Tensile Fatigue									R = +0.1
Material: T300/V378A									Frequency = 30 Hz
									Function: Sine
Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
I35-6	0/±45/90[1]	350	90.10	9.01	85	328,700	42	---	
I36-6	0/±45/90[1]	350	90.10	9.01	85	613,500	24	---	
I37-8	0/±45/90[1]	350	90.10	9.01	85	960,500	34	---	
I14-6	0/±45/90[1]	350	87.45	8.75	82.5	1,229,400	38	---	
I36-7	0/±45/90[1]	350	87.45	8.75	82.5	2,128,300	20	---	overheated to 525°F
I39-10	0/±45/90[1]	350	87.45	8.75	82.5	332,400	17	---	
I12-8	0/±45/90[1]	350	84.80	8.48	80	102,400	52	---	
I13-8	0/±45/90[1]	350	84.80	8.48	80	660,000	29	---	
I38-8	0/±45/90[1]	350	84.80	8.48	80	626,100	22	---	
I39-8	0/±45/90[1]	350	84.80	8.48	80	432,200	32	---	
I40-8	0/±45/90[1]	350	84.80	8.48	80	2,320,600	54	---	
I13-2	0/±45/90[1,2]	72	88.45	8.85	95	260,100	59	---	
I14-2	0/±45/90[1,2]	72	88.45	8.85	95	2,191,900	45	---	
I36-1	0/±45/90[1,2]	72	88.45	8.85	95	2,012,300	75	---	
I39-1	0/±45/90[1,2]	72	88.45	8.85	95	225,500	57	---	
I13-1	0/±45/90[1,2]	72	83.79	8.38	90	61,300	53	---	
I14-1	0/±45/90[1,2]	72	83.79	8.38	90	932,600	54	---	
I37-1	0/±45/90[1,2]	72	83.79	8.38	90	1,587,800	32	---	
I12-2	0/±45/90[1,2]	72	79.14	7.91	85	265,700	42	---	
I28-2	0/±45/90[1,2]	72	79.14	7.91	85	1,252,600	50	---	
I38-2	0/±45/90[1,2]	72	79.14	7.91	85	1,024,200	58	---	
I40-1	0/±45/90[1,2]	72	79.14	7.91	85	2,399,300	52	---	

[1] $(0, +45, -45, 0, 0, -45, \_45, 0, 90, 0)_s$ - 20 ply

[2] These specimens had a 0.1935 inch (0.491 cm) hole in center of test section. Stresses based on net cross-sectional area.

Test: Tensile-Tensile Fatigue — R = +0.1

Material: HyE 1076J — Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
J3-5	±45	72	17.82	1.78	80	11,600	9	---	
J6-1	±45	72	17.82	1.78	80	1,700	11	---	
J7-4	±45	72	17.82	1.78	80	5,400	6	---	
J9-6	±45	72	17.82	1.78	80	6,500	9	---	
J11-7	±45	72	17.82	1.78	80	8,700	9	---	
J4-5	±45	72	15.60	1.56	70	200,300	8	---	
J6-6	±45	72	15.60	1.56	70	110,200	24	---	
J8-5	±45	72	15.60	1.56	70	153,800	20	---	
J10-5	±45	72	15.60	1.56	70	72,600	19	---	
J12-5	±45	72	15.60	1.56	70	188,800	12	---	
J7-5	±45	72	14.48	1.45	65	1,202,100	7	---	
J8-7	±45	72	14.48	1.45	65	883,600	8	---	
J10-7	±45	72	14.48	1.45	65	1,005,800	4	---	
J12-7	±45	72	14.48	1.45	65	1,475,500	8	---	
J5-4	±45	72	13.37	1.34	60	5,000,000+	9	20.07	test terminated
J4-1	±45	260	14.02	1.40	85	43,400	18	---	
J6-5	±45	260	14.02	1.40	85	42,200	5	---	
J8-1	±45	260	14.02	1.40	85	17,700	11	---	
J10-1	±45	260	14.02	1.40	85	17,300	24	---	
J12-1	±45	260	14.02	1.40	85	12,000	8	---	

Test: Tensile-Tensile Fatigue

Material: HyE 1076J

R = +0.1

Frequency = .30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
J3-4	±45	260	13.19	1.32	80	83,800	10	---	
J5-5	±45	260	13.19	1.32	80	133,800	14	---	
J7-7	±45	260	13.19	1.32	80	106,500	10	---	
J9-5	±45	260	13.19	1.32	80	25,700	26	---	
J11-6	±45	260	13.19	1.32	80	60,500	10	---	
J4-6	±45	260	12.37	1.24	75	924,300	5	---	
J6-7	±45	260	12.37	1.24	75	935,200	7	---	
J8-6	±45	260	12.37	1.24	75	158,400	7	---	
J10-6	±45	260	12.37	1.24	75	513,200	7	---	
J12-6	±45	260	12.37	1.24	75	397,800	6	---	
J14-3	0/±45/90'	72	105.14	10.51	90	4,800	46	---	
J17-2	0/±45/90'	72	105.14	10.51	90	8,900	42	---	
J21-3	0/±45/90'	72	105.14	10.51	90	88,200	65	---	
J23-7	0/±45/90'	72	105.14	10.51	90	2,400	30	---	
J25-3	0/±45/90'	72	105.14	10.51	90	285,000	38	---	
J20-3	0/±45/90'	72	102.22	10.22	87.5	25,300	39	---	
J22-4	0/±45/90'	72	102.22	10.22	87.5	575,800	25	---	
J24-2	0/±45/90'	72	102.22	10.22	87.5	417,300	36	---	
J13-3	0/±45/90'	72	99.30	9.93	85	580,800	46	---	
J15-3	0/±45/90'	72	99.30	9.93	85	6,349,300	23	---	
J17-3	0/±45/90'	72	99.30	9.93	85	546,200	42	---	
J22-3	0/±45/90'	72	99.30	9.93	85	3,077,000	32	---	
J23-8	0/±45/90'	72	99.30	9.93	85	12,400	39	---	

'(0, +45, -45, 0, 0, -45, +45, 0 90, 0)s -20 ply

Test: Tensile-Tensile Fatigue

Material: HyE 1076J

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
J13-4	0/±45/90[1]	72	93.46	9.35	80	628,800	37	---	
J16-3	0/±45/90[1]	72	93.46	9.35	80	10,000,000+	27	118.31	
J15-6	0/±45/90[1]	260	108.06	10.81	90	34,000	53	---	
J16-4	0/±45/90[1]	260	108.06	10.81	90	1,500	25	---	
J21-5	0/±45/90[1]	260	108.06	10.81	90	3,500	44	---	
J23-6	0/±45/90[1]	260	108.06	10.81	90	3,100	40	---	
J14-4	0/±45/90[1]	260	96.06	9.61	80	12,800	60	---	
J16-5	0/±45/90[1]	260	96.06	9.61	80	218,400	38	---	
J20-5	0/±45/90[1]	260	96.06	9.61	80	170,000	30	---	
J22-5	0/±45/90[1]	260	96.06	9.61	80	154,500	35	---	
J25-4	0/±45/90[1]	260	96.06	9.61	80	57,600	52	---	
J14-5	0/±45/90[1]	260	90.05	9.01	75	1,098,300	29	---	
J15-4	0/±45/90[1]	260	90.05	9.01	75	1,808,700	36	---	
J20-4	0/±45/90[1]	260	90.05	9.01	75	1,648,000	37	---	
J21-4	0/±45/90[1]	260	90.05	9.01	75	1,298,500	33	---	
J24-3	0/±45/90[1]	260	90.05	9.01	75	1,450,900	33	---	

[1](0, +45, -45, 0, 0, -45, +45, 0, 90, 0,)s -20 ply

Test: Tensile-Tensile Fatigue | R = +0.1

Material: HVE 1076J | Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
J17-1	0/±45/90 [1,2]	72	97.35	9.74	110	900	---	---	
J21-1	0/±45/90 [1,2]	72	97.35	9.74	110	600	---	---	
J15-1	0/±45/90 [1,2]	72	97.35	9.74	110	993,800	55	---	
J25-2	0/±45/90 [1,2]	72	97.35	9.74	110	6,178,200	54	---	
J16-1	0/±45/90 [1,2]	72	92.93	9.29	105	2,207,400	52	---	
J20-2	0/±45/90 [1,2]	72	92.93	9.29	105	1,100	9	---	
J22-2	0/±45/90 [1,2]	72	92.93	9.29	105	1,100	---	---	
J24-1	0/±45/90 [1,2]	72	92.93	9.29	105	700	---	---	
J23-9	0/±45/90 [1,2]	72	90.00	9.00	102	1,593,700	49	---	
J13-1	0/±45/90 [1,2]	72	88.50	8.85	100	900	---	---	
J15-2	0/±45/90 [1,2]	72	88.50	8.85	100	10,000,000+	46	118.35	
J20-1	0/±45/90 [1,2]	72	88.50	8.85	100	1,483,700	34	---	
J22-1	0/±45/90 [1,2]	72	88.50	8.85	100	620,900	45	---	
J23-10	0/±45/90 [1,2]	72	88.50	8.85	100	900	5	---	
J14-1	0/±45/90 [1,2]	72	84.08	8.41	95	10,000,000+	44	102.44	

[1] $(0, +45, -45, 0, 0, -45, +45, 0, 90, 0)_s$ -20 ply

[2] These specimens had a 0.1935 inch (0.491 cm) hole in center of test section. Stresses based on net cross-sectional area.

Test: Tensile-Tensile Fatigue

Material: G-160/6535-1

R = +0.1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
K9-5	±45°	72	14.05	1.41	85	6,600	8		
K9-4	±45°	72	14.05	1.41	85	11,200	25		
K7-5	±45°	72	14.05	1.41	85	4,500	9		
K5-5	±45°	72	14.05	1.41	85	2,300	9		
K4-5	±45°	72	14.05	1.41	85	2,700	8		
K10-5	±45°	72	12.40	1.24	75	35,400	41		
K10-4	±45°	72	12.40	1.24	75	102,100	8		
K7-6	±45°	72	12.40	1.24	75	142,700	7		
K6-3	±45°	72	12.40	1.24	75	89,400	8		
K4-6	±45°	72	12.40	1.24	75	34,700	7		
K11-3	±45°	72	10.74	1.07	65	655,100	13		
K11-2	±45°	72	10.74	1.07	65	840,300	15		
K8-2	±45°	72	10.74	1.07	65	623,100	26		
K6-4	±45°	72	10.74	1.07	65	1,169,700	26		
K5-4	±45°	72	10.74	1.07	65	479,200	3		
K10-6	±45°	260	13.23	1.32	85	3,900	21		
K9-7	±45°	260	13.23	1.32	85	4,500	10		
K8-4	±45°	260	13.23	1.32	85	1,300	8		
K6-5	±45°	260	13.23	1.32	85	7,800	24		
K4-7	±45°	260	13.23	1.32	85	2,700	30		

Test: Tensile-Tensile Fatigue | R = +0.1

Material: G-160/6535-1 | Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
K11-4	±45°	260	10.89	1.09	70	302,000	3		
K9-6	±45°	260	10.89	1.09	70	35,200	2		
K8-3	±45°	260	10.89	1.09	70	85,700	7		
K6-7	±45°	260	10.89	1.09	70	52,300	4		
K5-6	±45°	260	10.89	1.09	70	108,900	19		
K11-5	±45°	260	8.56	0.86	55	2,092,400	0		
K9-8	±45°	260	8.56	0.86	55	3,313,500	2		
K8-5	±45°	260	8.56	0.86	55	3,014,200	2		
K7-7	±45°	260	8.56	0.86	55	6,265,800	2		
K6-6	±45°	260	8.56	0.86	55	4,881,600	0		
K37-4	0/45/90°[1]	72	77.79	7.78	85	1,400	6		
K37-8	0/45/90°[1]	72	77.79	7.78	85	30,600	28		
K38-5	0/45/90°[1]	72	77.79	7.78	85	6,700	19		
K39-1	0/45/90°[1]	72	77.79	7.78	85	200	1		
K39-7	0/45/90°[1]	72	77.79	7.78	85	300	0		
K38-1	0/45/90°[1]	72	73.22	7.32	80	131,600	20		
K38-6	0/45/90°[1]	72	73.22	7.32	80	10,600	26		
K39-2	0/45/90°[1]	72	73.22	7.32	80	10,000,000+	13		
K39-8	0/45/90°[1]	72	73.22	7.32	80	175,000	9		
K37-2	0/45/90°[1]	72	73.22	7.32	80	3,900	27		

[1] $(0,90,+45,-45,0,0,-45,+45,0,0)_s$-20 ply.

Test: Tensile-Tensile Fatigue R = +0.1

Material: G-160/6535-1 Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
K37-1	0/45/90[1]	72	68.64	6.86	75	46,700	30		
K37-6	0/45/90[1]	72	68.64	6.86	75	1,094,400	18		
K38-2	0/45/90[1]	72	68.64	6.86	75	1,500	5		
K38-8	0/45/90[1]	72	68.64	6.86	75	10,136,000+	21		
K39-6	0/45/90[1]	72	68.64	6.86	75	39,700	39		
K24-3	0/45/90[2]	72	86.34	8.63	95	700	5		
K24-7	0/45/90[2]	72	86.34	8.63	95	200	---		
K25-6	0/45/90[2]	72	86.34	8.63	95	3,200	9		
K26-3	0/45/90[2]	72	86.34	8.63	95	400	6		
K26-6	0/45/90[2]	72	86.34	8.63	95	4,600	30		
K24-2	0/45/90[2]	72	81.79	8.18	90	453,400	23		
K24-6	0/45/90[2]	72	81.79	8.18	90	5,600	36		
K25-4	0/45/90[2]	72	81.79	8.18	90	217,300	24		
K25-8	0/45/90[2]	72	81.79	8.18	90	30,900	33		
K26-5	0/45/90[2]	72	81.79	8.18	90	13,900	39		
K24-5	0/45/90[2]	72	77.25	7.73	85	363,400	25		
K25-2	0/45/90[2]	72	77.25	7.73	85	2,578,800	15		
K25-7	0/45/90[2]	72	77.25	7.73	85	24,300	13		
K26-4	0/45/90[2]	72	77.25	7.73	85	321,700	32		
K26-7	0/45/90[2]	72	77.25	7.73	85	11,600	18		

[1] $(0,90,+45,-45,0,0,-45,+45,0,0)_s$-20 ply; [2] $(0,45,-45,0,0,-45,45,0,90,0)_s$-20 ply.

Test: Tensile-Tensile Fatigue

R = +0.1

Material: G-160/6535-1

Frequency = 30 Hz

Function: Sine

Specimen Number	Fiber Orientation	Test Temp. (°F)	Max. Stress (10^3 psi)	Min. Stress (10^3 psi)	Max. Stress (% ult.)	Cycles to Failure	Temp. Rise (°F)	Residual Strength (10^3 psi)	Remarks
K34-2	0/±45[3]	72	87.55	8.76	90	13,500	27		
K34-6	0/±45[3]	72	87.55	8.76	90	200	---		
K35-5	0/±45[3]	72	87.55	8.76	90	900	11		
K35-9	0/±45[3]	72	87.55	8.76	90	2,600	25		
K36-5	0/±45[3]	72	87.55	8.76	90	500	10		
K36-7	0/±45[3]	72	82.69	8.27	85	8,656,400	26		
K34-5	0/±45[3]	72	82.69	8.27	85	10,500	27		
K35-3	0/±45[3]	72	82.69	8.27	85	6,900	22		
K35-8	0/±45[3]	72	82.69	8.27	85	30,500	22		
K36-2	0/±45[3]	72	82.69	8.27	85	300	---		
K34-4	0/±45[3]	72	77.82	7.78	80	1,790,000	18		
K34-8	0/±45[3]	72	77.82	7.78	80	1,500	10		
K35-7	0/±45[3]	72	77.82	7.78	80	5,600	18		
K36-1	0/±45[3]	72	77.82	7.78	80	4,585,200	14		
K36-8	0/±45[3]	72	77.82	7.78	80	2,700	18		

[3] $(0,45,-45,0,0,-45,45,0)_s$-16 ply.

APPENDIX J

CREEP AND STRESS RUPTURE DATA

All of the tensile creep data generated during this program, along with residual strengths of specimens which "ran out" to 500 hours are presented in this section. The residual strengths were all determined with a 72°F (22°C) tensile test regardless of what temperature the specimen saw during the creep test.

The stress rupture data were also obtained from these same specimens with the characteristic of interest being time to fracture rather than elongation.

Summaries of these data are presented in Sections 4.1 through 4.6 in both tabular and graphical form.

In the succeeding tables the specimen numbering system can be used to identify the material being tested. The letter, appearing first, in the specimen numbering code indicates the material, as follows:

F - T300/AFR800
G - SiC/5506
H - HyE 2034D
I - T300/V378A
J - HyE 1076J
K - G-160/6535-1

Test: Creep
Orient: 0°
Spec. No: F1-13
Temp: 72°F(22°C)
Stress: 163.8 ksi 92% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7872	
0.10	7884	
0.25	7913	
0.50	7908	
1	7919	
2	7916	
3	7917	
4	7920	
5	7919	
6	7916	
6.5	7917	
24	7934	
168	7974	
504	7992	
Recovery		
0	102	Load off

Test: Creep
Orient: 0°
Spec. No: F3-8
Temp: 72°F(22°C)
Stress: 163.8 ksi 92 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8073	
0.017	8076	
0.10	8085	
0.33	8089	
0.50	8090	
1	8092	
2	8092	
3	8092	
5	8092	
6	8089	
7	8086	
8	8088	
24	8106	
72	8130	
144	8122	
217	8108	
317	8092	
504	8090	
Recovery		
0	13	Load off
1	3	
3	-10	

Test: Creep
Orient: 0°
Spec. No: F3-10
Temp: 72°F(22°C)
Stress 163.8 ksi 92% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	missed initial reading	
0.017	8037	
0.10	8044	
0.25	8048	
0.50	8050	
1	8058	
2	8058	
4	8059	
8	8061	
24	8084	
144	8117	
483	8114	
531	8064	
Recovery		
0	42	Load off

Test: Creep		
Orient: 0°		
Spec. No: F4-1		
Temp: 72°F(22°C)		
Stress: 143.4 ksi 80 % ult.		
Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6818	
0.017	6818	
0.10	6818	
0.25	6817	
0.50	6816	
1	6816	
2	6813	
3.1	6806	
4	6803	
5	6807	
6	6815	
7	6813	
24	6824	
96	6900	
120	6900	
190	6864	
263	6840	
336	6830	
435	6818	
504	6812	
Recovery		
0	-13	Load off
1	0	
3	0	

Test: Creep		
Orient: 0°		
Spec. No: F4-15		
Temp: 72°F(22°C)		
Stress: 143.4 ksi 80 % ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6770	
0.017	6772	
0.10	6768	
0.25	6769	
0.50	6770	
1	6764	
2	6763	
3.1	6759	
4	6754	
5	6764	
6	6765	
7	6764	
24	6776	
96	6790	
120	6804	
190	6822	
263	6802	
336	6788	
435	6780	
504	6770	
Recovery		
0	-15	Load off
1	- 1	
3	- 6	

Test: Creep		
Orient: 0°		
Spec. No: F5-2		
Temp: 72°F(22°C)		
Stress 143.4 ksi 80 % ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6563	
0.017	6563	
0.10	6562	
0.25	6562	
0.50	6560	
1	6562	
2	6559	
3.1	6552	
4	6548	
5	6556	
6	6556	
7	6557	
24	6570	
96	6588	
120	6600	
190	6618	
263	6610	
336	6588	
435	6576	
504	6569	
Recovery		
0	-26	Load off
1	-12	
3	-13	

Test: Creep
Orient: 0°
Spec. No: F1-15
Temp: 260°F(127°C)
Stress: 174.5 ksi 90 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	8361	
failed	before 0.017 hr.	
Recovery		

Test: Creep
Orient: 0°
Spec. No: F3-2
Temp: 260°F(127°C)
Stress: 174.5 ksi 90 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8334	
0.017	8363	
failed	before 0.1 hr.	
Recovery		

Test: Creep
Orient: 0°
Spec. No: F4-12
Temp: 260°F(127°C)
Stress 174.5 ksi 90 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8531	
0.017	8531	
0.10	8531	
0.25	8531	
0.50	8531	
1	8532	
2	8532	
3	8537	
4	8525	
6	8529	
24	8554	
51.5	8604	
79	8680	
310	9726	
486	---	gage failed
500+		
specimen	did not fail	
Recovery		

Test: Creep
Orient: 0°
Spec. No: F1-7
Temp: 260°F (127°C)
Stress: 155.1 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7436	
0.017	7442	
0.10	7460	
0.25	7474	
0.50	7477	
1	7475	
2	7484	
3	7481	
5.3	7488	
7.3	7490	
47.5	7508	
148	7560	
217	7577	
366	7589	
413	7597	
480	7612	
503	7601	
Recovery		
0	74	Load off
1	16	
2	14	

Test: Creep
Orient: 0°
Spec. No: F1-12
Temp: 260°F (127°C)
Stress: 155.1 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7574	
0.017	7584	
0.10	7600	
0.25	7620	
0.50	7633	
1	7648	
2	7672	
3	7685	
5	7700	
7.2	7711	
47.5	7795	
148	7901	
217	7927	
366	7970	
413	7977	
480	7986	
503	8001	
Recovery		
0	528	Load off
1	480	
2	465	

Test: Creep
Orient: 0°
Spec. No: F3-16
Temp: 260°F (127°C)
Stress 155.1 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	---	gage failed
0.05	specimen failed	
Recovery		

Test: Creep
Orient: 0°
Spec. No: F1-5
Temp: 260°F (127°C)
Stress: 135.7 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6648	
0.017	6659	
0.25	6661	
0.50	6664	
1	6664	
4	6671	
5	6683	
6	6684	
7	6681	
8	6683	
24	6690	
72	6704	
271	6724	
344	6718	
434.5	6715	
480	6718	
580	6730	
Recovery		
0	111	Load off

Test: Creep
Orient: 0°
Spec. No: F4-6
Temp: 260°F (127°C)
Stress: 135.7 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6705	
0.017	6713	
0.25	6719	
0.50	6714	
1	6716	
4	6723	
5	6725	
6	6721	
7	~6723	
8	6723	
24	6731	
77	6735	
271	6712	
344	6720	
434.5	6709	
480	6714	
580	6727	
Recovery		
0	128	Load off

Test: Creep
Orient: 0°
Spec. No: F5-11
Temp: 260°F (127°C)
Stress 135.7 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6767	
0.017	6775	
0.25	6777	
0.50	6776	
1	6775	
4	6785	
5	6826	
6	6822	
7	6832	
8	6832	
24	6832	
77	6840	
271	6815	
344	6850	
434.5	6843	
480	6845	
580	6858	
Recovery		
0	132	Load off

Test: Creep		
Orient: 0°		
Spec. No: F6-17		
Temp: 350°F(177°C)		
Stress: 156.2 ksi 90 % ult.		
Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7673	
0.017	7670	
0.10	7654	
0.25	7659	
0.50	7669	
1	7672	
2	7687	
4	7706	
5	7718	
6	7729	
7	7740	
24	7837	
72	7995	
168	8153	
264	8270	
336	8323	
433	8449	
504	8477	
Recovery		
0	705	Load off
1	655	
2	652	
3	642	

Test: Creep		
Orient: 0°		
Spec. No: F22-1		
Temp: 350°F(177°C)		
Stress: 156.2 ksi 90 % ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8310	
0.017	8324	
0.10	8337	
0.25	8340	
0.50	8359	
1	8318	
2	8307	
4	8329	
5	8313	
6	8314	
7	8306	
24	8280	
168	8221	
264	8221	
360	8216	
432	8256	
503	8271	
Recovery		
0	366	Load off
1	306	
2	296	
3	291	

Test: Creep		
Orient: 0°		
Spec. No: F22-8		
Temp: 350°F(177°C)		
Stress 156.2 ksi 90 % ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7981	
0.017	8009	
0.10	8014	
0.25	8010	
0.50	8067	
1	8078	
2	8086	
4	8091	
5	8092	
6	8092	
7	8090	
24	8131	
72	8220	
168	8243	
264	8298	
336	8348	
433	8436	
504	8469	
Recovery		
0	440	Load off
1	355	
2	829	
3	312	

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Test: Creep
Orient: 0°
Spec. No: F5-10
Temp: 350°F(177°C)
Stress: 138.8 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6493	
0.017	6493	
0.10	6490	
0.25	6490	
0.50	6494	
1	6496	
2.5	6497	
3	6491	
4	6491	
5	6504	
6	6504	
24	6503	
168	6508	
264	6519	
360	6553	
432	6553	
502	6572	
Recovery		
0	143	Load off
1	134	
2	125	
3	116	

Test: Creep
Orient: 0°
Spec. No: F6-2
Temp: 350°F(177°C)
Stress: 138.8 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7163	
0.017	7175	
0.10	7181	
0.25	7190	
0.50	7196	
1.25	7180	
2	7203	
4	7209	
5	7209	
6	7216	
7	7216	
24	7245	
72	7268	
173	7307	
264	7330	
336	7353	
433	7372	
503	7396	
Recovery		
0	174	Load off
1	148	
2	145	
3	138	

Test: Creep
Orient: 0°
Spec. No: F6-6
Temp: 350°F(177°C)
Stress 138.8 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6637	
0.017	6645	
0.10	6651	
0.25	6662	
0.50	6662	
1	6677	
2.5	6688	
3	6675	
4	6664	
5	6673	
6	6678	
24	6677	
168	6694	
264	6678	
360	6713	
432	6726	
502	6742	
Recovery		
0	180	Load off
1	170	
2	157	
3	152	

Test: Creep

Orient: 0°

Spec. No: F6-11

Temp: 350°F (177°C)

Stress: 138.8 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7390	
0.017	7402	
0.10	7410	
0.25	7394	
0.50	7403	
1.1	7412	
5	7439	
6	7462	
71	7493	
172	7493	
265	7502	
436	7542	
600	7542	

Recovery

0	297	Load off
1	200	
3.5	188	
4	184	

Test:

Orient:

Spec. No:

Temp:

Stress: ksi % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks

Recovery

Test:

Orient:

Spec. No:

Temp:

Stress ksi % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks

Recovery

Test: Creep
Orient: 0°
Spec. No: F1-17
Temp: 350°F(177°C)
Stress: 121.5 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6259	
0.05	6308	
0.20	6349	
0.50	6365	
1	5388	
2	6429	
3	6449	
4	6467	
5	6479	
6	6499	
24	6651	
95	6726	
144	6769	
192	6794	
264	6822	
360	6875	
432	6880	
503	6880	
Recovery		
0	753	Load off
1	680	
2	662	
3	652	

Test: Creep
Orient: 0°
Spec. No: F3-14
Temp: 350°F(177°C)
Stress: 121.5 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	missed reading	
0.75	6526	
1	6535	
2	6541	
3	6551	
4	6557	
5	6558	
6	6566	
24	6622	
95	6723	
144	6762	
192	6792	
264	6812	
360	6847	
432	6880	
503	6892	
Recovery		
0	1402	Load off
1	1368	
2	1355	
3	1353	

Test: Creep
Orient: 0°
Spec. No: F5-4
Temp: 350°F(177°C)
Stress 121.5 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5678	
0.05	5672	
0.20	5659	
0.50	5652	
1	5650	
2	5640	
3	5638	
4	5638	
5	5643	
6	5648	
24	5618	
95	558[illegible]	
144	5590	
192	5582	
254	5573	
360	5558	
432	5554	
503	5545	
Recovery		
0	-116	Load off
1	-138	
2	-146	
3	-148	

Test: Creep

Orient: 90°

Spec. No: F8-10

Temp: 72°F(22°C)

Stress: 3.21 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	failed on loading	

Recovery

Test: Creep

Orient: 90°

Spec. No: F11-3

Temp: 72°F(22°C)

Stress: 3.21 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failed on	loading

Recovery

Test: Creep

Orient: 90°

Spec. No: F13-4

Temp: 72°F(22°C)

Stress 3.21 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failed on loading	

Recovery

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Test: Creep
Orient: 90°
Spec. No: F8-4
Temp: 72°F(22°C)
Stress: 2.75 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	missed reading	
0.017	1864	
0.10	1879	
0.25	1888	
0.50	1893	
1	1909	
2	1918	
5	1937	
8	1943	
24	1965	
145	2068	
194	2095	
318	2147	
482	2206	
530.4	2191	
Recovery		
0	308	Load off
1	286	

Test: Creep
Orient: 90°
Spec. No: F9-3
Temp: 72°F(22°C)
Stress: 2.75 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	missed reading	
0.017	1893	
0.10	1905	
0.25	1919	
0.50	1928	
1	1933	
2	1950	
5	1968	
8	1981	
24	2002	
145	2116	
194	2142	
318	2199	
482	2261	
530.4	2248	
Recovery		
0	376	Load off
1	314	

Test: Creep
Orient: 90°
Spec. No: F9-5
Temp: 72°F(22°C)
Stress 2.75 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1891	
0.10	1903	
specimen failed		
Recovery		

Test: Creep
Orient: 90°
Spec. No: F7-3
Temp: 72°F(22°C)
Stress: 2.29 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1514	
0.017	1530	
0.10	1547	
0.25	1552	
0.50	1563	
1	1565	
2	1583	
3	1599	
5	1616	
6	1619	
7	1627	
8	1627	
24	1642	
72	1670	
148	1680	
245	1687	
435	1828	
482	1864	
602	1913	
Recovery		
0	428	Load off
1	390	
3	378	

Test: Creep
Orient: 90°
Spec. No: F8-7
Temp: 72°F(22°C)
Stress: 2.29 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1486	
0.017	1500	
0.10	1514	
0.25	1520	
0.50	1528	
1	1534	
2	1548	
3	1568	
5	1582	
6	1588	
7	1589	
8	1594	
24	1608	
72	1634	
145	1645	
245	1735	
435	1790	
482	1821	
602	1874	
Recovery		
0	403	Load off
1	363	
3	351	

Test: Creep
Orient: 90°
Spec. No: F9-8
Temp: 72°F(22°C)
Stress 2.29 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1543	
0.017	1553	
0.10	1567	
0.25	1579	
0.50	1581	
1	1591	
2	1599	
3	1618	
5	1630	
6	1638	
7	1640	
8	1644	
24	1660	
72	1688	
145	1702	
245	1806	
435	1857	
482	1885	
602	1959	
Recovery		
0	420	Load off
1	374	
3	358	

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Test: Creep
Orient: 90°
Spec. No: F9-7
Temp: 260°F(127°C)
Stress: 2.80 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	strain gage failed	
	on loading	
556	specimen did not fail	
Recovery		

Test: Creep
Orient: 90°
Spec. No: F12-4
Temp: 260°F(127°C)
Stress: 2.80 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2215	
0.10	2193	
0.25	2185	
0.50		failure
Recovery		

Test: Creep
Orient: 90°
Spec. No: F7-5
Temp: 260°F(127°C)
Stress: 2.80 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failed on	loading
Recovery		

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Test: Creep

Orient: 90°

Spec. No: F7-10

Temp: 260°F(127°C)

Stress: 2.57 ksi 55 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1954	
0.017	1992	
0.10	2009	
0.33	2009	
0.50	2017	
1	2037	
2	2037	
3	2040	
5	2049	
6	2037	
7	2037	
24.3	2003	
72	1990	
144	2019	
240	2046	
313	2064	
408	2092	
506	2112	

Recovery

0	209	Load off
1	147	
3	126	

Test: Creep

Orient: 90°

Spec. No: F11-10

Temp: 260°F(127°C)

Stress: 2.57 ksi 55 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1916	
0.017	1941	
0.10	1994	
0.33	2102	
0.50	2135	
1	2169	
2	2217	
3	2233	
5	2267	
6	2279	
7	2293	
24.3	2408	
72	2560	
144	2696	
240	2854	
313	2940	
408	3053	
506	3155	

Recovery

0	1380	Load off
1	1292	
3	1249	

Test: Creep

Orient: 90°

Spec. No: F14-5

Temp: 260°F(127°C)

Stress 2.57 ksi 55 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1955	
0.017	1966	
0.10	1976	
0.33	2031	
0.50	2034	
1	2059	
2	2082	
3	2091	
5	2100	
6	2105	
7	2106	
24.3	2109	
72	2143	
144	2190	
240	2272	
313	2319	
408	2340	
506	2393	

Recovery

0	501	Load off
1	409	
3	375	

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Test: Creep
Orient: 90°
Spec. No: F7-11
Temp: 260°F (127°C)
Stress: 2.34 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1937	
0.017	1973	
0.10	2006	
0.25	2050	
0.50	2062	
1	2082	
2	2105	
4	2142	
5	2157	
6	2163	
7	2172	
28	2286	
55	2408	
287	2808	
462	3013	
508	3056	
Recovery		
0	1139	Load off
1	1080	
2	1044	
3	1016	

Test: Creep
Orient: 90°
Spec. No: F9-4
Temp: 260°F (127°C)
Stress: 2.34 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1731	
0.017	1756	
0.10	1766	
0.25	1799	
0.50	1801	
1	1814	
2	1829	
4	1837	
5	1838	
6	1831	
7	1836	
28	1868	
55	1870	
287	1941	
462	1952	
508	1954	
Recovery		
0	209	Load off
1	183	
2	168	
3	163	

Test: Creep
Orient: 90°
Spec. No: F13-9
Temp: 260°F (127°C)
Stress: 2.34 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1762	
0.017	1781	
0.10	1791	
0.25	1807	
0.50	1809	
1	1817	
2	1816	
4	1819	
5	1825	
6	1827	
7	1827	
28	1906	
55	1952	
287	2146	
462	2214	
508	2244	
Recovery		
0	708	Load off
1	662	
2	653	
3	639	

Test: Creep

Orient: 90°

Spec. No: F34-1

Temp: 350°F(177°C)

Stress: 2.71 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2319	
0.017	2398	
0.10	3401	
0.25	3860	
0.50	4112	
1	4800	
2	5052	
3	5084	
4	5059	
5	5070	
6	5065	
24	5374	
68	--	failure

Recovery

Test: Creep

Orient: 90°

Spec. No: F34-8

Temp: 350°F(177°C)

Stress: 2.71 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5412	
0.017		failure

Recovery

Test: Creep

Orient: 90°

Spec. No: F34-2

Temp: 350°F(177°C)

Stress 2.71 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failed on loading	

Recovery

AFR-800

Test: Creep
Orient: 90°
Spec. No: F34-3
Temp: 350°F(177°C)
Stress: 2.17 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1902	
0.017	2069	
0.10	2342	
0.25	2519	
0.50	2631	
1	2713	
3	2740	
4	2788	
5	2764	
6	2780	
24	2720	
122	2804	
186	2951	
205		failure
Recovery		

Test: Creep
Orient: 90°
Spec. No: F34-5
Temp: 350°F(177°C)
Stress: 2.17 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1801	
0.017	1902	
0.13	1954	
0.25	1954	
0.50	1981	
1	2023	
2	2091	
4	2157	
5	2182	
7	2225	
24	2464	
168	3289	
267	3694	
335	3929	
437	4282	
528	4580	
Recovery		
0	2801	Load off
1	2652	
2	2626	
4.5	2545	

Test: Creep
Orient: 90°
Spec. No: F34-11
Temp: 350°F(177°C)
Stress 2.17 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2830	
0.017	3188	
0.03		failure
Recovery		

Test: Creep
Orient: 90°
Spec. No: F34-7
Temp: 350°F(177°C)
Stress: 1.63 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2230	0 = 1000
0.017	2245	
0.10	2277	
0.25	2305	
0.50	2371	
1	2468	
2	2589	
5.2	2731	
6	2754	
7	2701	
48	2689	
52	3091	
72	3289	
145	3618	
240	3760	
312	3900	
414	4140	
505	4164	
Recovery		
0	2876	Load off
1	2529	
2	2365	
4.5	2198	

Test: Creep
Orient: 90°
Spec. No: F34-9
Temp: 350°F(177°C)
Stress: 1.63 ksi 30% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1108	
0.017	1108	
0.10	1134	
0.25	1161	
0.50	1243	
1	1323	
2	1389	
5.2	1511	
6	1538	
7	1631	
48	2492	
72	2597	
145	2893	
240	3392	
312	3717	
414	4218	
505	4472	
Recovery		
0	3318	Load off
1	3035	
2	2964	
4.5	2736	

Test: Creep
Orient: 90°
Spec. No: F34-10
Temp: 350°F(177°C)
Stress 1.63 ksi 30 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2468	
0.017	2591	
0.10	2777	
0.25	2828	
0.50	2985	
1	3085	
2	3231	
5.2	3477	
6	3524	
7	3581	
48	4480	
72	4677	
145	5215	
240	5932	
312	6426	
414	7348	
505	8057	
Recovery		
0	6471	Load off
1	6065	
2	6013	
4.5	5892	

AFR-800

Test: Creep
Orient: ±45°
Spec. No: F28-10
Temp: 72°F(22°C)
Stress: 16.27 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	8330	
0.017	8690	
0.117	9214	
0.25	9456	
0.50	9634	
1	9867	
2	10054	
24	10924	
91	11508	
131	11684	
183	12028	
260	12148	
361	12275	
453	12351	
528	12387	
Recovery		
0	3840	Load off
1	2445	
1.5	2362	

Test: Creep
Orient: ±45°
Spec. No: F29-3
Temp: 72°F(22°C)
Stress: 16.27 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8610	
0.017	8940	
0.117	9459	
0.25	9710	
0.50	9895	
1	10140	
2	10333	
24	11225	
91	11820	
131	12000	
183	12343	
260	12455	
361	12588	
453	12656	
528	12689	
Recovery		
0	4020	Load off
1	2433	
1.5	2347	

Test: Creep
Orient: ±45°
Spec. No: F33-9
Temp: 72°F(22°C)
Stress 16.27 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8090	
0.017	8350	
0.117	8845	
0.25	9090	
0.50	9273	
1	9507	
2	9692	
24	10585	
91	11175	
131	11354	
183	11692	
260	11815	
361	11954	
453	12033	
528	12072	
Recovery		
0	4430	Load off
1	2647	
1.5	2564	

Test: Creep
Orient: +45°
Spec. No: F23-2
Temp: 72°F(22°C)
Stress: 13.94 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6540	
0.017	6653	
0.10	6779	
0.25	6935	
0.583	7235	
1	7297	
2	7450	
3	7542	
5.2	7601	
7.2	7654	
47.4	8187	4112
148	8725	
217	8793	
366	9254	
413	9267	4127
480	9362	
503	9404	
Recovery		
0	2674	Load off
1	1972	
2	1932	

Test: Creep
Orient: +45°
Spec. No: F23-4
Temp: 72°F(22°C)
Stress: 13.94 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6449	
0.017	6543	
0.10	6630	
0.25	6747	
0.583	7036	
1	7114	
2	7230	
3	7294	
5.2	7362	
7.2	7392	
47.4	7887	
148	8376	
217	8440	
366	8894	
413	8895	
480	8967	
503	9001	
Recovery		
0	2336	Load off
1	1811	
2	1760	

Test: Creep
Orient: +45°
Spec. No: F25-2
Temp: 72°F(22°C)
Stress 13.94 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6457	
0.017	6536	
0.10	6620	
0.25	6778	
0.583	7064	
1	7129	
2	7280	
3	7371	
5.2	7378	
7.2	7497	
47.4	7874	
148	8478	
217	8546	
366	8978	
413	8989	
480	9067	
503	9119	
Recovery		
0	2400	Load off
1	1908	
2	1864	

Test: Creep
Orient: ±45°
Spec. No: F24-2
Temp: 72°F(22°C)
Stress: 11.62 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5320	
0.017	5461	
0.10	5617	
0.25	5696	
0.50	5770	
1	5869	
2	5942	
4	6046	
5	6071	
6	6082	
7	6110	
28.5	6418	
55	6551	
287	6836	
462	7120	
508	7115	
Recovery		
0	1582	Load off
1	1051	
2	967	
3	945	

Test: Creep
Orient: ±45°
Spec. No: F27-2
Temp: 72°F(22°C)
Stress: 11.62 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6225	
0.017	6351	
0.10	6556	
0.25	6676	
0.50	6785	
1	6907	
2	7024	
4	7160	
5	7203	
6	7230	
7	7277	
28.5	7670	
55	7852	
287	8294	
462	8641	
508	8688	
Recovery		
0	2320	Load off
1	1532	
2	1382	
3	1357	

Test: Creep
Orient: ±45°
Spec. No: F27-7
Temp: 72°F(22°C)
Stress 11.62 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5412	
0.017	5485	
0.10	5620	
0.25	5693	
0.50	5770	
1	5860	
2	5944	
4	6025	
5	6057	
6	6072	
7	6112	
28.5	6412	
55	6544	
287	6952	
462	7240	
508	7293	
Recovery		
0	1725	Load off
1	1086	
2	983	
3	921	

Test: Creep
Orient: ±45°
Spec. No: F29-1
Temp: 260°F(127°C)
Stress: 13.44 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	12578	
0.017	15152	
0.10	18404	
0.167	19291	
0.25	---	failure

Recovery

Test: Creep
Orient: ±45°
Spec. No: F30-7
Temp: 260°F(127°C)
Stress: 13.44 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	12083	
0.017	13405	
0.10	15543	
0.167	16362	
0.25	16876	failure

Recovery

Test: Creep
Orient: ±45°
Spec. No: F32-2
Temp: 260°F(127°C)
Stress 13.44 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Gage failure	
0.25		failure

Recovery

Test: Creep
Orient: ±45°
Spec. No: F30-11
Temp: 260°F(127°C)
Stress: 11.76 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7818	
0.017	9154	
0.10	10116	
0.25	10805	
0.50	11275	
1	11857	
2	12437	
2.5	12635	
4.5	13160	
5.5	13331	
6.6	13480	
7.5	13585	
24	14538	
48	14180	
74	16238	
144	17074	
366	18704	
484	19334	
506	19474	
Recovery		
0	13529	Load off
2.3	11777	
3	11627	
4	11517	

Test: Creep
Orient: ±45°
Spec. No: F32-3
Temp: 260°F(127°C)
Stress: 11.76 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7917	
0.017	8917	
0.10	10174	
0.25	11010	
0.50	11470	
1	11975	
2	12499	
2.5	12678	
4.5	13169	
5.5	13335	
6.6	13498	
7.5	13602	
24	14634	
48	15440	
74	15977	
144	16921	
366	19213	
484	20176	
506	20350	
Recovery		
0	14488	Load off
2.3	12437	
3	12266	
4	12170	

Test: Creep
Orient: ±45°
Spec. No: F33-2
Temp: 260°F(127°C)
Stress 11.76 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6433	
0.017	7155	
0.10	8184	
0.25	8719	
0.50	9085	
1	9469	
2	9926	
2.5	10077	
4.5	10542	
5.5	10701	
6.6	10840	
7.5	10930	
24	11512	
48	12349	
74	12830	
144	13815	
366	15390	
484	15898	
506	15986	
Recovery		
0	10766	Load off
2.3	10014	
3	9904	
4	9790	

Test: Creep
Orient: ±45°
Spec. No: F26-3
Temp: 260°F (127°C)
Stress: 10.08 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5039	
0.017	5212	
0.10	5585	
0.25	5788	
0.50	5973	
1	6197	
2	6426	
4	6685	
5	6768	
6	6833	
7	6959	
24	7576	
48	7891	
120	8463	
216	8955	
314	9317	
385	9572	
528	9958	
Recovery		
0	5166	Load off
1	4362	
2	4217	
4	4058	

Test: Creep
Orient: ±45°
Spec. No: F26-5
Temp: 260°F (127°C)
Stress: 10.08 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4987	
0.017	5161	
0.10	5392	
0.25	5580	
0.50	5802	
1	6055	
2	6342	
4	6663	
5	6774	
6	6862	
7	6954	
24	7649	
48	8409	
120	9551	
216	10517	
314	11308	
385	11829	
528	12690	
Recovery		
0	7707	Load off
1	6473	
2	6168	
4	5910	

Test: Creep
Orient: ±45°
Spec. No: F26-9
Temp: 260°F (127°C)
Stress 10.08 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6025	
0.017	6228	
0.10	6950	
0.25	7249	
0.42	7434	
0.50	7504	
1	7799	
2	8175	
4	8580	
5	9214	
6	9624	
7	10001	
24	12067	
48	13482	
120	15606	
216	17545	
314	19022	
385	19931	
528	21504	
Recovery		
0	15676	Load off
1	13988	
2	13611	
4	13266	

AFR-800

Test: Creep
Orient: ±45°
Spec. No: F24-8
Temp: 350°F(177°C)
Stress: 9.76 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	gage failed	
222	specimen failed	

Recovery

Test: Creep
Orient: ±45°
Spec. No: F26-7
Temp: 350°F(177°C)
Stress: 9.76 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7442	
0.083	8438	
0.167	9321	
0.50	12195	
1	18526	
1.5	20000	(approx.)
2	gage failed	
25	specimen failed	

Recovery

Test: Creep
Orient: ±45°
Spec. No: F26-11
Temp: 350°F(177°C)
Stress 9.76 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	missed initial reading	
0.10	10281	
0.167	10628	
0.50	11774	
1	12635	
2	13634	
3	14492	
4	15633	
5	16717	
6	17527	
24	gage failed	
222	specimen overheated	
	and failed when	
	F24-8 failed	

Recovery

AFR-800

Test: Creep
Orient: ±45°
Spec. No: F29-5
Temp: 350°F(177°C)
Stress: 8.14 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7768	
0.017	11070	
0.10	16046	
0.25	17873	
0.50	19734	
1	21746	
2.1	24062	
4	26246	
5	26939	
6	27685	
7	28179	
24	33711	
100	gage failed	
504	no failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: F30-8
Temp: 350°F(177°C)
Stress: 8.14 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8596	
0.017	gage failed	
504	no failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: F33-7
Temp: 350°F(177°C)
Stress 8.14 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7137	
0.017	8299	
0.10	9999	
0.25	11090	
0.50	12112	
1	14119	
2.1	17002	
4	19408	
5	20156	
6	20883	
7	21322	
24	gage failed	
504	no failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: F27-9
Temp: 350°F(177°C)
Stress: 6.51 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6939	
0.017	9187	
0.083	10704	
0.10	10930	
0.28	14452	
0.50	16101	
1	17879	
2	19196	
3	20120	
4.5	20789	
5	20151	
6	21459	
24	28191	
96	30668	
121.3	33593	
167	gage failed	
504	no failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: F28-1
Temp: 350°F(177°C)
Stress: 6.51 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	9778	
0.017	14448	
0.083	20391	
0.10	20406	
0.28	22333	
0.50	24471	
1	25544	
2	26425	
3	26997	
4.5	27218	
5	27291	
6	27400	
24	28211	
96	29824	
121.3	30563	
167	32137	
191	32580	
264	gage failed	
504	no failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: F33-11
Temp: 350°F(177°C)
Stress 6.51 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	23065	
0.017	gage failed	
432	failure	

Recovery

SiC/5506

Test: Creep
Orient: ±45°
Spec. No: G28-7
Temp: 72°F(22°C)
Stress: 13.86 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7790	
0.017	8352	
0.10	9077	
0.25	9634	
0.50	10053	
1	10545	
2	11069	
6.5	12079	
7	12211	
25	13414	
145	15490	
312	16368	
360	16566	
438	16851	
534	17166	
Recovery		
0	10178	Load off
1	7640	
1.5	7433	

Test: Creep
Orient: ±45°
Spec. No: G29-3
Temp: 72°F(22°C)
Stress: 13.86 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8350	
0.017	8935	
0.10	9718	
0.25	10303	
0.50	10817	
1	11387	
2	11989	
6.5	13187	
7	13335	
25	14740	
145	17384	
312	18487	
360	18740	
438	19120	
534	19533	
Recovery		
0	11830	Load off
1	9169	
1.5	952	

Test: Creep
Orient: ±45°
Spec. No: G30-4
Temp: 72°F(22°C)
Stress 13.86 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8180	
0.017	8730	
0.10	9837	
0.25	10545	
0.50	11206	
1	11884	
2	12818	
6.5	gage out	
534	no failure	
Recovery		

SiC/5506

Test: Creep
Orient: ±45°
Spec. No: G27-7
Temp: 72°F(22°C)
Stress: 12.13 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5289	
0.017	5767	
0.10	6167	
0.25	6487	
0.50	6729	
1	7004	
2	--	
4.3	7698	
5	7792	
6	7885	
7	7947	
24	8627	
48	9045	
192	10081	
360	10501	
408	10590	
486	10735	
533	10808	
Recovery		
0	5600	Load off
1	4214	
2	3978	
2.5	3913	

Test: Creep
Orient: ±45°
Spec. No: G27-8
Temp: 72°F(22°C)
Stress: 12.13 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5367	
0.017	5681	
0.10	6017	
0.25	6297	
0.50	6519	
1	6764	
2	7033	
4.3	7379	
5	7460	
6	7543	
7	7597	
24	8175	
48	8514	
192	9380	
360	9706	
408	9773	
486	9379	
533	9928	
Recovery		
0	5010	Load off
1	3615	
2	3382	
2.5	3314	

Test: Creep
Orient: ±45°
Spec. No: G28-3
Temp: 72°F(22°C)
Stress 12.13 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5700	
0.017	6318	
0.10	6897	
0.25	7210	
0.50	7431	
1	7708	
2	8023	
25	9189	
146	10330	
192	10645	
360	11248	
453	11457	
504	11555	
Recovery		
0	5640	Load off
1	3887	
2	3600	

SiC/5506

Test: Creep
Orient: ±45°
Spec. No: G16-6
Temp: 72°F(22°C)
Stress: 10.39 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5110	
0.017	5338	
0.10	5776	
0.25	6025	
0.50	6224	
1	6435	
1.5	6550	
4	6939	
6	7130	
168	8795	
412	9140	
483	9208	
579	9317	
Recovery		
0	4320	Load off
1	3066	
2	2860	
3	2759	

Test: Creep
Orient: ±45°
Spec. No: G29-2
Temp: 72°F(22°C)
Stress: 10.39 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5320	
0.017	5541	
0.10	6008	
0.25	6290	
0.50	6506	
1	6744	
1.5	6873	
4	7316	
6	7525	
168	9515	
412	9963	
483	10050	
579	10189	
Recovery		
0	4879	Load off
1	3578	
2	3350	
3	3253	

Test: Creep
Orient: ±45°
Spec. No: G31-1
Temp: 72°F(22°C)
Stress 10.39 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5312	
0.017	5493	
0.10	5900	
0.25	6161	
0.50	6362	
1	6581	
1.5	6701	
4	7102	
6	7297	
168	9068	
412	9470	
483	9551	
579	9677	
Recovery		
0	4650	Load off
1	3227	
2	3005	
3	2910	

SiC/5506

Test: Creep
Orient: ±45°
Spec. No: G12-3
Temp: 260°F (127°C)
Stress: 5.12 ksi 44 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5139	
0.017		gage failed
504		no failure

Recovery

Test: Creep
Orient: ±45°
Spec. No: G16-5
Temp: 260°F (127°C)
Stress: 5.12 ksi 44 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4157	
0.017	4607	
0.10	5041	
0.25	5355	
0.50	7752	
1	9956	
2	10858	
25	13778	
146	15715	
192	16119	
360	17398	
453	18131	
504	18528	

Recovery

0	14756	Load off
1	6905	
2	6486	

Test: Creep
Orient: ±45°
Spec. No: G31-8
Temp: 260°F (127°C)
Stress 5.12 ksi 44 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3709	
0.017	4179	
0.10	4856	
0.25	6093	
0.50	7978	
1	10095	
2	10847	
25	12728	
146	13822	
192	14094	
360	15124	
453	15557	
504	15793	

Recovery

0	13066	Load off
1	12262	
2	12038	

SiC/5506

Test: Creep
Orient: ±45°
Spec. No: G28-5
Temp: 260°F(127°C)
Stress: 8.07 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	11579	
0.017	17765	
0.10	20601	
0.25	21806	
0.50	22931	
1	23930	
2	27336	
5	32579	
6	33463	
7		gage failed
308		no failure
Recovery		

Test: Creep
Orient: ±45°
Spec. No: G29-7
Temp: 260°F(127°C)
Stress: 8.07 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	41063	
0.017	41063	gage failed
7	specimen	failure
Recovery		

Test: Creep
Orient: ±45°
Spec. No: G31-6
Temp: 260°F(127°C)
Stress 8.07 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	11144	
0.017	16063	
0.10	19274	
0.25	22144	
0.50	24287	
1	26229	
2		gage failed
92	specimen	failure
Recovery		

SiC/5506

Test: Creep
Orient: ±45°
Spec. No: G12-2
Temp: 260°F(127°C)
Stress: 5.76 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6146	
0.017	7494	
0.10	9008	
0.25	10286	
0.50	11360	
1	12640	
2	14219	
4	16280	
5	17045	
6	17695	
7	18144	
24	gage failed	
509	no failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: G28-4
Temp: 260°F(127°C)
Stress: 5.76 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4266	
0.017	4771	
0.10	7824	
0.25	8960	
0.50	9755	
1	10400	
2	11023	
4	12322	
5	12907	
6	13362	
7	13706	
24	16054	
25	16157	
26	16288	
28	16512	
29	16662	
48	18046	
125	21956	
221	25127	
390	28699	
509	31161	

Recovery

0	28078	Load off
1.5	26301	
2	26093	

Test: Creep
Orient: ±45°
Spec. No: G31-5
Temp: 260°F(127°C)
Stress 5.76 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4346	
0.017	5332	
0.10	11017	
0.25	12344	
0.50	13490	
1	14773	
2	16409	
4	17850	
5	18357	
6	18886	
7	19212	
24	23204	
25	23341	
26	23466	
28	23724	
29	23854	
48	25767	
125	30478	
221	34266	
390	38899	
509	41791	

Recovery

0	38163	Load off
1.5	36119	
2	35838	

SiC/5506

Test: Creep
Orient: +45°
Spec. No: G12-6
Temp: 350°F(177°C)
Stress: 3.17 ksi 40 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	20978	
0.017	gage failed	
0.10	failure	
Recovery		

Test: Creep
Orient: +45°
Spec. No: G28-8
Temp: 350°F(177°C)
Stress: 3.17 ksi 40 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	gage failed	
0.017	failure	
Recovery		

Test: Creep
Orient: +45°
Spec. No: G30-2
Temp: 350°F(177°C)
Stress: 3.17 ksi 40 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	gage failed	
0.10	failure	
Recovery		

SiC/5506

Test: Creep
Orient: ±45°
Spec. No: G29-5
Temp: 350°F(177°C)
Stress: 1.59 ksi 20 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	17447	
0.017	23304	
0.05	gage failed	
517	no failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: G27-3
Temp: 350°F(177°C)
Stress: 1.59 ksi 20 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	886	
0.017	927	
0.10	968	
0.25	1010	
0.50	1045	
1	1105	
2	1194	
3	1743	
3.5	failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: G16-7
Temp: 350°F(177°C)
Stress 1.59 ksi 20% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	8428	
0.017	11189	
0.10	14202	
0.25	17596	
0.50	19992	
1	23225	
2	gage failed	
517	no failure	

Recovery

SiC/5506

Test: 500 Hr. Creep
Orient: ±45°
Spec. No: G12-8
Temp: 350°F(177°C)
Stress: 1.19 ksi 15 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	11003	
0.017	12688	
0.10	14705	
0.25	17316	
0.42	25343	
1	gage failed	
503	no failure	

Recovery

Test: 500 Hr. Creep
Orient: ±45°
Spec. No: G16-8
Temp: 350°F(177°C)
Stress: 1.19 ksi 15 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	gage failed	
503	no failure	

Recovery

Test: 500 Hr. Creep
Orient: ±45°
Spec. No: G30-1
Temp: 350°F(177°C)
Stress 1.19 ksi 15% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	13259	
0.017	14420	
0.10	17653	
0.25	gage failed	
503	no failure	

Recovery

SiC/5506

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G32-5
Temp: 72°F (22°C)
Stress: 83.48 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4580	
0.017	4589	
0.10	4599	
0.25	4607	
0.50	4611	
1	4617	
2	4621	
4	4633	
5	4635	
6	4637	
7	4643	
24	4651	
25	4655	
26	4651	
28	4652	
29	4646	
48	4650	
125	4676	
222	4702	
341	4705	
390	4731	
509	4730	
Recovery		
0	168	Load off
1	136	
2	130	

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G44-2
Temp: 72°F (22°C)
Stress: 83.48 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4376	
0.017	4386	
0.10	4394	
0.25	4397	
0.50	4402	
1	4406	
3	4413	
4	4437	
5	4440	
6	4444	
29	4457	
148	4461	
317	4462	
436	4457	
507	4468	
Recovery		
0	120	Load off
1	94	
2	88	
3	85	

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G41-2
Temp: 72°F (22°C)
Stress: 83.48 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4429	
0.017	4438	
0.10	4447	
0.25	4454	
0.50	4459	
1	4463	
3	4475	
4	4505	
5	4505	
6	4510	
29	4528	
148	4536	
317	4541	
436	4536	
507	4549	
Recovery		
0	340	Load off
1	304	
2	298	
3	292	

SiC/5506

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G33-4
Temp: 72°F(22°C)
Stress: 71.55 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3485	
0.017	3493	
0.10	3499	
0.33	3503	
0.50	3511	
1	3519	
2	3520	
3	3519	
24	3539	
165	3556	
245	3556	
433	3567	
530	3567	
Recovery		
0	-125	Load off
1	-149	

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G33-8
Temp: 72°F(22°C)
Stress: 71.55 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3870	
0.017	3894	
0.10	3902	
0.33	3910	
0.50	3917	
1	3923	
2	3928	
3	3927	
24	3954	
165	3971	
245	3978	
433	3983	
530	3992	
Recovery		
0	130	Load off
1	105	

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G43-4
Temp: 72°F(22°C)
Stress 71.55 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	gage failed	
506	no failure	
Recovery		

SiC/5506

Test: Creep		
Orient: 0°/±45°/90°		
Spec. No: G32-7		
Temp: 72°F(22°C)		
Stress: 59.63 ksi 50% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3127	
0.017	3135	
0.10	3139	
0.25	3143	
0.67	3145	
1	3148	
3	3150	
4	3152	
5	3155	
95	3181	
144	3178	
244	3187	
411	3174	
508	3178	
Recovery		
0	24	Load off
1	8	

Test: Creep		
Orient: 0°/±45°/90°		
Spec. No: G34-6		
Temp: 72°F(22°C)		
Stress: 59.63ksi 50% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2543	
0.017	2545	
0.10	2552	
0.25	2554	
0.67	2558	
1	2558	
3	2562	
4	2560	
5	2560	
95	2587	
144	2580	
244	2613	
411	2623	
508	2634	
Recovery		
0	571	Load off
1	485	

Test: Creep		
Orient: 0°/±45°/90°		
Spec. No: G39-9		
Temp: 72°F(22°C)		
Stress 59.63 ksi 50% ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3327	
0.017	3339	
0.10	3347	
0.50	3356	
1	3360	
2	3364	
24	3387	
144	3403	
291	3395	
388	3404	
524	3405	
Recovery		
0	61	Load off
0.5	46	
1.0	44	

SiC/5506

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G32-2
Temp: 260°F (127°C)
Stress: 82.04 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4646	
0.017	4665	
0.10	4680	
0.25	4683	
0.50	4683	
1	4683	
2	4683	
4	4687	
5	4687	
6	4688	
7	4696	
68	4538	
122	4485	
244	4431	
405	4387	
500	4391	
Recovery		
0	-153	Load off
0.5	-240	
1	-283	
2	-301	
3	-310	

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G40-8
Temp: 260°F (127°C)
Stress: 82.04 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4413	
0.017	4439	
0.10	4450	
0.25	4461	
0.50	4454	
1	4466	
3	4511	
4	4521	
5	4531	
6	4539	
28	4586	
77	4621	
147	4654	
217	4660	
315	4669	
478	4729	
503	4726	
Recovery		
0	287	Load off
1	61	
3	32	

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G43-6
Temp: 260°F (127°C)
Stress: 82.04 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	gage failed	
503	no failure	
Recovery		

SiC/5506

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G40-5
Temp: 260°F(127°C)
Stress: 70.32 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	gage failed	
521	no failure	

Recovery

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G41-8
Temp: 260°F(127°C)
Stress: 70.32 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3769	
0.017	3785	
0.10	3792	
0.25	3795	
0.50	3804	
1	3806	
4	3824	
5	3825	
6	3830	
28	3866	
99	3913	
195	3949	
231	gage failed	
521	no failure	

Recovery

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G36-9
Temp: 260°F(127°C)
Stress 70.32 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	Failed on	loading

Recovery

SiC/5506

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G33-9
Temp: 260°F(127°C)
Stress: 58.60 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3133	
0.017	3149	
0.10	3146	
0.25	3173	
0.50	3177	
1	3182	
1.5	3188	
3	3193	
4	3201	
5	3205	
6	3205	
28	3226	
78	3250	
144	3263	
241	3276	
309	3282	
406	3296	
475	3305	
500	3305	
Recovery		
0	157	Load off
1	113	
3	104	

Test: Creep
Orient: 0°/+45°/90°
Spec. No: G35-3
Temp: 260°F(127°C)
Stress: 58.60 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3207	
0.017	3211	
0.10	3207	
0.25	3238	
0.50	3246	
1	3255	
1.5	3261	
3	3270	
4	3275	
5	3291	
6	3294	
28	3328	
78	3354	
144	3370	
241	3383	
309	3393	
406	3400	
475	3424	
500	3433	
Recovery		
0	264	Load off
1	187	
3	164	

Test: Creep
Orient: 0°/+45°/90°
Spec. No: G39-5
Temp: 260°F(127°C)
Stress 58.60 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3236	
0.017	3249	
0.10	3272	
0.25	3291	
0.50	3304	
1	3309	
2	3326	
3	3335	
69	3391	
166	3417	
234	3434	
330	3455	
399	3469	
452	3476	
500	3485	
Recovery		
0	279	Load off
0.5	221	
1	206	
2	192	
3	183	

SiC/5506

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G35-5
Temp: 350°F(177°C)
Stress: 60.41 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	gage failed	
504	no failure	

Recovery

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G35-8
Temp: 350°F(177°C)
Stress: 60.41ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3440	
0.017	3543	
0.10	3611	
0.25	3641	
0.50	3650	
1	3662	
2	3697	
3	3715	
5	3760	
6	3770	
7	3782	
25	3862	
104	3938	
264	3979	
367	4056	
486	4107	
504	4114	

Recovery

0	507	Load off
1	332	
2	306	
4	275	

Test: Creep
Orient: 0°/±45°/90°
Spec. No: G36-5
Temp: 350°F(177°C)
Stress 60.41 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failed on loading	

Recovery

HyE 2034D

Test: Creep
Orient: ±45°
Spec. No: H18-5
Temp: 72°F(22°C)
Stress: 8.68 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3390	
0.017	3464	
0.10	3550	
0.25	3657	
0.50	3714	
1	3775	
2	3825	
3	3869	
5	3925	
6	3942	
7	3963	
8	3980	
96	4310	
175	4440	
270	4617	
344	4669	
434	4714	
530	4802	
Recovery		
0	1392	Load off
1	840	
3	737	

Test: Creep
Orient: ±45°
Spec. No: H15-2
Temp: 72°F(22°C)
Stress: 8.68 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2896	
0.017	2970	
0.10	3032	
0.25	3121	
0.50	3167	
1	3211	
2	3242	
3	3274	
5	3320	
6	3330	
7	3344	
8	3355	
96	3592	
175	3686	
270	3842	
344	3857	
434	3882	
530	3963	
Recovery		
0	1038	Load off
1	602	
3	528	

Test: Creep
Orient: ±45°
Spec. No: H16-8
Temp: 72°F(22°C)
Stress 8.68 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3030	
0.017	3097	
0.10	3150	
0.25	3239	
0.50	3282	
1	3328	
2	3353	
3	3384	
5	3431	
6	3444	
7	3458	
8	3468	
96	3722	
175	3814	
270	3972	
344	3991	
434	4023	
530	4098	
Recovery		
0	1080	Load off
1	626	
3	545	

HyE 2034D

Test: Creep		
Orient: ±45°		
Spec. No: H16-7		
Temp: 72°F(22°C)		
Stress: 7.30 ksi 70% ult.		
Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2841	
0.017	2886	
0.10	2957	
0.25	3015	
0.50	3060	
1	3101	
2	3150	
3	3178	
21	3388	
120	3659	
283	3832	
361	3972	
456	3914	
504	3912	
Recovery		
0	961	Load off
1	688	
2	660	
3	645	

Test: Creep		
Orient: ±45°		
Spec. No: H18-4		
Temp: 72°F(22°C)		
Stress: 7.30 ksi 70 % ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2938	
0.017	2982	
0.10	3049	
0.25	3096	
0.50	3135	
1	3170	
2	3210	
3	3230	
21	3395	
120	3605	
283	3749	
361	3874	
456	3808	
504	3808	
Recovery		
0	856	Load off
1	619	
2	596	
3	578	

Test: Creep		
Orient: ±45°		
Spec. No: H19-7		
Temp: 72°F(22°C)		
Stress 7.30 ksi 70 % ult.		
Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3010	
0.017	3093	
0.10	3182	
0.25	3238	
0.50	3289	
1	3330	
2	3381	
3	3404	
21	3604	
120	3859	
283	4027	
361	4157	
456	4102	
504	4102	
Recovery		
0	943	Load off
1	715	
2	679	
3	661	

HyE 2034D

Test: Creep
Orient: +45°
Spec. No: H12-9
Temp: 72°F(22°C)
Stress: 5.43 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1970	
0.017	2055	
0.10	2100	
0.25	2130	
0.50	2152	
1	2177	
3	2322	
4	2235	
5	2243	
6	2254	
28	2344	
77	2425	
148	2479	
216	2506	
316	2545	
478	2609	
504	2608	
Recovery		
0	597	Load off
1	461	
3	421	

Test: Creep
Orient: +45°
Spec. No: H14-7
Temp: 72°F(22°C)
Stress: 5.43 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2260	
0.017	2321	
0.10	2362	
0.25	2396	
0.50	2419	
1	2445	
3	2492	
4	2505	
5	2513	
6	2523	
28	2615	
77	2701	
148	2759	
216	2785	
316	2832	
478	2899	
504	2901	
Recovery		
0	667	Load off
1	503	
3	459	

Test: Creep
Orient: +45°
Spec. No: H19-6
Temp: 72°F(22°C)
Stress 5.43 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1983	
0.017	2037	
0.10	2068	
0.25	2098	
0.50	2114	
1	2137	
3	2175	
4	2186	
5	2192	
6	2201	
28	2279	
77	2349	
148	2398	
216	2421	
316	2459	
473	2520	
504	2522	
Recovery		
0	550	Load off
1	385	
3	359	

Test: Creep
Orient: ±45°
Spec. No: H10-6
Temp: 260°F(127°C)
Stress: 4.70 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1945	
0.017	1993	
0.10	2046	
0.25	2084	
0.50	2120	
1	2162	
2	2213	
3	2238	
4	2263	
5	2287	
6	2301	
7	2320	
24	2441	
79	2725	
198	3040	
312	3228	
414	3337	
504	3431	
Recovery		
0	1605	Load off
1	1426	
2	1407	
4.5	1367	

Test: Creep
Orient: ±45°
Spec. No: H11-10
Temp: 260°F(127°C)
Stress: 4.70 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1761	
0.017	1779	
0.10	1815	
0.25	1845	
0.50	1876	
1	1909	
2	1950	
3	1973	
4	1991	
5	2004	
6	2018	
7	2029	
24	2126	
79	2384	
198	2596	
312	2730	
414	2805	
504	2884	
Recovery		
0	1099	Load off
1	965	
2	950	
4.5	915	

Test: Creep
Orient: ±45°
Spec. No: H16-6
Temp: 260°F(127°C)
Stress 4.70 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1750	
0.017	1829	
0.10	1880	
0.25	1918	
0.50	1957	
1	1998	
2	2049	
3	2076	
4	2104	
5	2122	
6	2132	
7	2149	
24	2271	
79	2549	
198	2886	
312	3102	
414	3279	
504	3397	
Recovery		
0	1656	Load off
1	1510	
2	1501	
4.5	1457	

HyE 2034D

Test: Creep
Orient: ±45°
Spec. No: H14-8
Temp: 260°F(127°C)
Stress: 6.57 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2826	
0.017	2946	
0.10	3075	
0.25	3250	
0.50	3262	
1	3256	
2	3281	
4	3332	
5	3340	
6	3364	
7	3377	
24	3544	
143	4257	
246	5137	
365	8697	
414	gage failed	
527	no failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: H15-6
Temp: 260°F(127°C)
Stress: 6.57 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2956	
0.017	2977	
0.10	3039	
0.25	3103	
0.50	3157	
1	3207	
2	3272	
4	3356	
5	3381	
6	3399	
7	3416	
24	3603	
143	4089	
246	4468	
356	4820	
414	4969	
527	5343	

Recovery

0	2417	Load off
0.5	2119	
1	2052	
2	1977	
3	1934	

Test: Creep
Orient: ±45°
Spec. No: H18-6
Temp: 260°F(127°C)
Stress 6.57 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3387	
0.017	3624	
0.10	3778	
0.25	3918	
0.50	4049	
1	4197	
2	4379	
4	4595	
5	4679	
6	4765	
7	4844	
69	7560	
122	11054	
221	Failure	

Recovery

HyE 2034D

Test: Creep
Orient: ±45°
Spec. No: H12-8
Temp: 260°F(127°C)
Stress: 5.63 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (µ in/in)	Remarks
0	2133	
0.017	2257	
0.10	2345	
0.25	2411	
0.50	2469	
1	2532	
2	2616	
4	2709	
5	2739	
6	2775	
7	2796	
24	3021	
143	3552	
246	3885	
365	4208	
414	4355	
527	4666	

Recovery

0	2403	Load off
0.5	2236	
1	2188	
2	2134	
3	2096	

Test: Creep
Orient: ±45°
Spec. No: H19-5
Temp: 260°F(127°C)
Stress: 5.63 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (µin/in)	Remarks
0	2466	
0.017	2506	
0.10	2553	
0.25	2595	
0.50	2634	
1	2684	
2	2752	
4	2818	
5	2841	
6	2860	
7	2877	
24	3045	
143	3336	
246	3493	
365	3662	
414	3727	
527	3872	

Recovery

0	1493	Load off
0.5	1299	
1	1251	
2	1207	
3	1189	

Test: Creep
Orient: ±45°
Spec. No: H16-5
Temp: 260°F(127°C)
Stress 5.63 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (µin/in)	Remarks
0	2437	
0.017	2448	
0.10	2567	
0.25	2631	
0.50	2696	
1	2765	
2	2859	
4	2861	
5	2993	
6	3027	
7	3054	
24	3310	
143	3858	
246	4186	
365	4545	
414	4655	
527	4959	

Recovery

0	2517	Load off
0.5	2309	
1	2259	
2	2204	
3	2171	

Test: Creep

Orient: ±45°

Spec. No: H10-7

Temp: 350°F(177°C)

Stress: 5.25 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2901	
0.017	3088	
0.10	3463	
0.25	3798	
0.50	4034	
1	4411	
3	5381	
4	5780	
5	6131	
6	6482	
24	gage failed	
114	---	failure

Recovery

Test: Creep

Orient: ±45°

Spec. No: H12-10

Temp: 350°F(177°C)

Stress: 5.25 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3203	
0.017	3361	
0.10	3716	
0.25	4155	
0.50	4548	
1	5123	
3	6313	
4	6936	
5	7549	
6	8195	
24	22391	
114	---	failure

Recovery

Test: Creep

Orient: ±45°

Spec. No: H14-9

Temp: 350°F(177°C)

Stress 5.25 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3953	
0.017	5028	
0.10	6869	
0.25	9087	
0.50	10676	
1	11506	
3.5	gage failed	
119	---	failure

Recovery

HyE 2034D

Test: Creep
Orient: ±45°
Spec. No: H10-9
Temp: 350°F(177°C)
Stress: 4.38 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3521	
0.017	3956	
0.13	5056	
0.25	5855	
0.50	6653	
1	7555	
3	9127	
4	9557	
5	9868	
6	10201	
24	12524	
95	17863	
191	gage failed	
502	no failure	

Recovery		

Test: Creep
Orient: ±45°
Spec. No: H17-10
Temp: 350°F(177°C)
Stress: 4.38 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1871	
0.017	2019	
0.10	2233	
0.25	2421	
0.50	2622	
1	2892	
3	3535	
4	3763	
5	3941	
6	4154	
24	6106	
95	9466	
191	11573	
263	13139	
365	gage failed	
502	no failure	

Recovery		

Test: Creep
Orient: ±45°
Spec. No: H19-8
Temp: 350°F(177°C)
Stress 4.38 ksi 50% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3617	
0.017	3719	
0.10	3980	
0.25	4135	
0.50	4299	
1	4487	
3	4871	
4	4989	
5	5082	
6	5185	
24	6082	
95	7804	
191	9010	
263	9649	
502	11497	

Recovery		
0	9792	Load off
0.5	9586	
1	9521	
2	9412	
3	[illegible]333	

HyE 2034D

Test: Creep
Orient: ±45°
Spec. No: H14-6
Temp: 350°F(177°C)
Stress: 3.50 ksi 40 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2031	
0.017	2196	
0.10	2985	
0.25	4697	
0.50	5761	
1	7579	
3	7848	
4	8286	
5	8886	
6	9282	
24	12562	
118	gage failed	
502	no failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: H17-8
Temp: 350°F(177°C)
Stress: 3.50 ksi 40% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1459	
0.017	1541	
0.10	1820	
0.25	1962	
0.50	2112	
1	2416	
3	2953	
4	3301	
5	3542	
6	3749	
24	6366	
118	10777	
220	13787	
317	18164	
454	gage failed	
502	no failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: H18-3
Temp: 350°F(177°C)
Stress 3.50 ksi 40 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1681	
0.017	1797	
0.10	2446	
0.25	2952	
0.50	3296	
1	3890	
3	5126	
4	12362	
5	13097	
6	13435	
24	16255	
118	20786	
220	gage failed	
502	no failure	

Recovery

HyE 2034D

Test: Creep
Orient: 0/±45/90°
Spec. No: H24-7
Temp: 72°F(22°C)
Stress: 60.66 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2165	
0.017	2169	
0.10	2171	
0.25	2178	
0.50	2176	
1	2176	
3	2180	
4	2166	
5	2149	
6	2150	
24	2170	
94	2185	
191	2195	
226	lost gage	
504	no failure	

Recovery

Test: Creep
Orient: 0/±45/90°
Spec. No: H24-8
Temp: 72°F(22°C)
Stress: 60.66 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2031	
0.017	2040	
0.10	2051	
0.25	2052	
0.50	2057	
1	2057	
3	2047	
4	2031	
5	2022	
6	2031	
24	2043	
94	1984	
191	2072	
226	lost gage	
504	no failure	

Recovery

Test: Creep
Orient: 0/±45/90°
Spec. No: H28-5
Temp: 72°F(22°C)
Stress: 60.66 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2031	
0.017	2034	
0.10	2046	
0.25	2049	
0.50	2051	
1	2051	
3	2044	
4	2031	
5	2022	
6	2030	
24	2049	
94	1991	
191	2075	
226	lost gage	
504	no failure	

Recovery

HyE 2034D

Test: Creep
Orient: 0/±45/90°
Spec. No: H24-2
Temp: 72°F(22°C)
Stress: 53.07 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1860	
0.017	1860	
0.10	1912	
0.50	1907	
1	1908	
2	1904	
4	1900	
5	1898	
7	1900	
24	1910	
78	1960	
143	1912	
240	1992	
311	1991	
434	1961	
503	1961	
Recovery		
0	137	Load off
0.5	137	
1	135	
3	143	

Test: Creep
Orient: 0/±45/90°
Spec. No: H20-1
Temp: 72°F(22°C)
Stress: 53.07 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1798	
0.017	1799	
0.10	1802	
0.50	1797	
1	1797	
2	1794	
4	1789	
5	1787	
7	1788	
24	1800	
78	1846	
143	1800	
240	1858	
311	1858	
434	1822	
503	1825	
Recovery		
0	59	Load off
0.5	55	
1	52	
3	61	

Test: Creep
Orient: 0/±45/90°
Spec. No: H28-4
Temp: 72°F(22°C)
Stress 53.07 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1771	
0.017	1774	
0.10	1775	
0.50	1772	
1	1769	
2	1768	
4	1762	
5	1759	
7	1763	
24	1768	
78	1816	
143	1768	
240	1847	
311	1845	
434	1818	
503	1817	
Recovery		
0	50	Load off
0.5	50	
1	49	
3	47	

HyE 2034D

Test: Creep
Orient: 0/±45/90°
Spec. No: H21-1
Temp: 72°F(22°C)
Stress: 45.49 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1711	
0.017	1711	
0.10	1717	
0.25	1716	
0.50	1717	
1	1717	
2	1718	
3	1718	
5	1716	
6	1712	
24	1691	
96	1745	
198	1730	
264	1747	
361	1730	
432	1730	
504	1702	
Recovery		
0	-4	Load off
1	-16	
2	-16	

Test: Creep
Orient: 0/±45/90°
Spec. No: H21-2
Temp: 72°F(22°C)
Stress: 45.49 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1579	
0.017	1581	
0.10	1581	
0.25	1581	
0.50	1582	
1	1581	
2	1584	
3	1583	
5	1580	
6	1577	
24	1560	
96	1603	
198	1587	
264	1604	
351	1582	
432	1581	
504	1558	
Recovery		
0	-16	Load off
1	-20	
2	-21	

Test: Creep
Orient: 0/±45/90°
Spec. No: H28-6
Temp: 72°F(22°C)
Stress: 45.49 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1500	
0.017	1500	
0.10	1500	
0.25	1499	
0.50	1500	
1	1500	
2	1500	
3	1499	
5	1496	
6	1496	
24	1476	
96	1520	
198	1502	
264	1520	
361	1502	
432	1500	
504	1474	
Recovery		
0	0	Load off
1	-21	
2	-23	

HyE 2034D

Test: Creep
Orient: 0/±45/90°
Spec. No: H20-2
Temp: 260°F(127°C)
Stress: 60.0 ksi 72% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2250	
0.017	2241	
0.10	2195	
0.25	2195	
0.50	2249	
1	2241	
2	2231	
4	2231	
5	2224	
6	2224	
7	2223	
21	failure	

Recovery

Test: Creep
Orient: 0/±45/90°
Spec. No: H24-6
Temp: 260°F(127°C)
Stress: 60.0 ksi 72 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1970	tab slipped
0.017	1962	
0.10	1962	
0.25	2036	
0.50	2051	
1	2051	
2	2045	
4	2042	
5	2042	
6	2037	
7	2033	
21	failure	

Recovery

Test: Creep
Orient: 0/±45/90°
Spec. No: H33-8
Temp: 260°F(127°C)
Stress 60.0 ksi 72% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1950	
0.017	1950	
0.10	1946	
0.25	2022	
0.50	2027	
1	2024	
2	2022	
4	2021	
5	2024	
6	2022	
7	2023	
21	failure	

Recovery

Test: Creep
Orient: 0/+45/90°
Spec. No: H27-3
Temp: 260°F(127°C)
Stress: 50.0 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1748	
0.017	1754	
0.10	1753	
0.25	1749	
0.50	1743	
1	1725	
3	170[illegible]	
4	1702	
5	1700	
6	1698	
24	1694	
95	1696	
169	1696	
263	1699	
334	1700	
413	1697	
508	1695	
Recovery		
0	-22	Load off
1	-27	
2	-24	

Test: Creep
Orient: 0/+45/90°
Spec. No: H28-2
Temp: 260°F(127°C)
Stress: 50.0 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	gage failed	
508	no failure	
Recovery		

Test: Creep
Orient: 0/+45/90°
Spec. No: H33-7
Temp: 260°F(127°C)
Stress 50.0 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1653	
0.017	1652	
0.10	1649	
0.25	1635	
0.50	1628	
1	1617	
3	1606	
4	1595	
5	1591	
6	1586	
24	1581	
95	1550	
169	1528	
263	1539	
335	1539	
413	1528	
508	1531	
Recovery		
0	-115	Load off
1	-113	
2	-109	

HyE 2034D

Test: Creep
Orient: 0/±45/90°
Spec. No: H20-6
Temp: 260°F (127°C)
Stress: 40.0 ksi 48 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1359	
0.017	1366	
0.10	1359	
0.25	1359	
0.50	1358	
1	1351	
2	1354	
3	1349	
6	1348	
7.5	1350	
24	1341	
96	1341	
145	1343	
267	1344	
361	1340	
432	1342	
504	1341	
Recovery		
0	-7	Load off
1	-2	
2	-4	
3	-2	

Test: Creep
Orient: 0/±45/90°
Spec. No: H26-7
Temp: 260°F (127°C)
Stress: 40.0 ksi 48% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1369	
0.017	1371	
0.10	1364	
0.25	1361	
0.50	1354	
1	1357	
2	1348	
3	1348	
6	1340	
7.5	1340	
24	1338	
96	1314	
145	1326	
267	1315	
361	1310	
432	1312	
504	1313	
Recovery		
0	-20	Load off
1	-22	
2	-19	
3	-19	

Test: Creep
Orient: 0/±45/90°
Spec. No: H27-9
Temp: 260°F (127°C)
Stress: 40.0 ksi 48 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1488	
0.017	1489	
0.10	1488	
0.25	1484	
0.50	1477	
1	1477	
2	1472	
3	1473	
6	1472	
7.5	1468	
24	1466	
96	1456	
145	1459	
267	1454	
361	1450	
432	1451	
504	1457	
Recovery		
0	2	Load off
1	-8	
2	-3	
3	-6	

HyE 2034D

Test: Creep
Orient: 0/±45/90°
Spec. No: H23-9
Temp: 350°F(177°C)
Stress: 66.22 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	2565	
0.017	2589	
0.10	2556	
0.25	2589	
0.50	2589	
1	2596	
1.5	2596	
6	2613	
7	2615	
8	2614	
103	2654	
240	2672	
342	2694	
357	failure	
Recovery		

Test: Creep
Orient: 0/±45/90°
Spec. No: H27-6
Temp: 350°F(177°C)
Stress: 66.22 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2311	
0.017	2320	
0.10	2301	
0.25	2331	
0.50	2345	
1	2344	
1.5	2348	
6	2162	
7	2398	
8	2390	
103	2460	
240	2511	
342	2544	
357	gage failed	
505	no failure	
Recovery		

Test: Creep
Orient: 0/±45/90°
Spec. No: H23-7
Temp: 350°F(177°C)
Stress 66.22 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2325	
0.017	2340	
0.10	2351	
0.25	2351	
0.50	2348	
1	2348	
1.5	2348	
6	2352	
7	2350	
8	2352	
103	2368	
240	2398	
342	2405	
408	2411	
505	2415	
Recovery		
0	201	
5	188	
5	172	
6	172	

HyE 2034D

Test: Creep
Orient: 0/±45/90°
Spec. No: H25-4
Temp: 350°F(177°C)
Stress: 57.95 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	1996	
0.017	1999	
0.10	1996	
0.25	1989	
0.50	1988	
1	1988	
2	1984	
4	1971	
7	1962	
24	1952	
76	1951	
142	1953	
247	1975	
342	1982	
413	1992	
505	1995	
Recovery		
0	-15	Load off
2	-24	
4	-33	
5	-32	

Test: Creep
Orient: 0/±45/90°
Spec. No: H26-6
Temp: 350°F(177°C)
Stress: 57.95 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1944	
0.017	1935	
0.10	1929	
0.25	1934	
0.50	1934	
1	1937	
2	1933	
4	1918	
7	1910	
24	1899	
76	1896	
142	1892	
247	1891	
342	1895	
413	1889	
505	1891	
Recovery		
0	-166	Load off
2	-184	
4	-184	
5	-187	

Test: Creep
Orient: 0/±45/90°
Spec. No: H27-8
Temp: 350°F(177°C)
Stress 57.95 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	2054	
0.017	2064	
0.10	2076	
0.25	2076	
0.50	2064	
1	2063	
2	2057	
4	2050	
7	2044	
24	2041	
76	2011	
142	1987	
247	1991	
342	1995	
413	2002	
505	2007	
Recovery		
0	118	Load off
2	109	
4	106	
5	104	

HyE 2034D

Test: Creep
Orient: 0/±45/90°
Spec. No: H21-4
Temp: 350°F (177°C)
Stress: 49.37 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	gage failed	
503	no failure	

Recovery

Test: Creep
Orient: 0/±45/90°
Spec. No: H23-5
Temp: 350°F (177°C)
Stress: 49.37 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1616	
0.017	1624	
0.10	1635	
0.25	1624	
0.50	1627	
1	1629	
2	1622	
4	1609	
5	1602	
6	1601	
7	1600	
24	1560	
95	1483	
174	1451	
364	1465	
431	1464	
503	1480	

Recovery

0	-74	Load off
0.5	-90	
3	-91	
7	-93	

Test: Creep
Orient: 0/±45/90°
Spec. No: H33-6
Temp: 350°F (177°C)
Stress 49.37 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	1604	
0.017	1607	
0.10	1600	
0.25	1601	
0.50	1598	
1	1604	
2	1603	
4	1595	
5	1599	
6	1603	
7	1600	
24	1623	
95	1660	
174	1683	
364	1701	
431	1698	
503	1687	

Recovery

0	160	Load off
0.5	168	
3	159	
7	164	

V378A

Test: Creep
Orient: ±45°
Spec. No: I3-4
Temp: 72°F (22°C)
Stress: 16.93 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	8762	
0.017	9276	
0.10	9913	
0.25	10265	
0.50	10514	
1	10807	
2	11130	
3	11333	
5	11628	
7	11949	
8	11942	
24	12554	
73	13428	
144	14323	
223	14850	
413	15549	
503	15644	
Recovery		
0	gage failed on unloading	

Test: Creep
Orient: ±45°
Spec. No: I4-10
Temp: 72°F(22°C)
Stress: 16.93 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8132	
0.017	8560	
0.10	9137	
0.25	9423	
0.50	9691	
1	10065	
2	10372	
3	10564	
5	10741	
6.5	108[illegible]2	
7.5	10995	
8	11031	
24	11807	
84	failure	
Recovery		

Test: Creep
Orient: ±45°
Spec. No: I7-8
Temp: 72°F(22°C)
Stress 16.93 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	9010	
0.017	9428	
0.10	10024	
0.25	10350	
0.50	10590	
1	10876	
2	11189	
3	11385	
5	11676	
7	11827	
8	11910	
24	12515	
73	13368	
144	14257	
223	14752	
413	15413	
503	15510	
Recovery		
0	7103	load off
0.5	6081	
1	5387	
2	5067	
3	4864	

V378A

Test: Creep
Orient: +45°
Spec. No: I5-4
Temp: 72°F(22°C)
Stress: 14.90 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (µ in/in)	Remarks
0	6330	
0.017	6728	
0.10	7128	
0.25	7300	
0.50	7465	
1	7650	
2	7830	
4	8051	
5	8137	
6	8200	
7	8264	
24	8752	
73	9616	
146	10965	
240	11517	
312	11838	
581	12379	
Recovery		
0	5957	load off
1	4527	

Test: Creep
Orient: +45°
Spec. No: I6-4
Temp: 72°F(22°C)
Stress: 14.90 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (µin/in)	Remarks
0	6578	
0.017	6894	
0.10	7275	
0.25	gage failed	
581	no failure	
Recovery		

Test: Creep
Orient: +45°
Spec. No: I8-4
Temp: 72°F(22°C)
Stress 14.90 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (µin/in)	Remarks
0	6744	
0.017	6955	
0.10	7341	
0.25	7521	
0.50	7695	
1	7888	
2	8080	
4	8306	
5	8386	
6	8467	
7	8481	
24	9043	
73	9944	
146	11342	
240	11872	
312	12189	
581	12717	
Recovery		
0	6125	load off
1	4559	

V378A

Test: Creep
Orient: ±45°
Spec. No: I3-7
Temp: 72°F(22°C)
Stress: 12.77 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5283	
0.017	5540	
0.10	5840	
0.25	6033	
0.50	6158	
1	6363	
2	6585	
3	6685	
5	6894	
7	7034	
8	7088	
24	7468	
73	8000	
146	8578	
223	8845	
413	9169	
503	9211	
Recovery		
0	3905	load off
0.5	3337	
1	3060	
2	2905	
3	2805	

Test: Creep
Orient: ±45°
Spec. No: I6-3
Temp: 72°F(22°C)
Stress: 12.77 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5682	
0.017	5907	
0.10	6198	
0.25	6387	
0.50	6556	
1	6721	
2	6946	
3	7045	
5	7223	
7	7360	
8	7407	
24	7764	
73	8246	
146	8726	
223	8944	
413	9217	
503	9256	
Recovery		
0	3903	load off
0.5	3314	
1	3020	
2	2859	
3	2753	

Test: Creep
Orient: ±45°
Spec. No: I8-1
Temp: 72°F(22°C)
Stress 12.77 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5811	
0.017	6022	
0.10	6312	
0.25	6507	
0.50	6678	
1	6851	
2	7082	
3	7186	
5	7374	
7	7504	
8	7558	
24	7928	
73	8466	
146	8992	
223	9209	
413	9513	
503	9553	
Recovery		
0	4050	load off
0.5	3390	
1	3086	
2	2915	
3	2807	

V378A

Test: Creep

Orient: ±45°

Spec. No: I3-10

Temp: 350°F(177°C)

Stress: 12.89 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	11492	
0.017	13527	
0.10	16264	
0.25	16961	
0.50	17336	
1	17856	
2	18465	
3	18886	
21	20535	
123	25690	
193	26420	
235	27249	
307	28551	
404	30384	
502	32124	
Recovery		
0	24193	load off
1	22158	
2	21851	
3	21610	

Test: Creep

Orient: ±45°

Spec. No: I4-1

Temp: 350°F(177°C)

Stress: 12.89 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	10487	
0.017	11861	
0.10	13050	
0.25	13458	
0.50	13950	
1	14615	
2	15018	
3	15325	
21	16965	
123	21609	
194	21993	
235	22869	
307	24266	
404	25714	
502	27366	
Recovery		
0	20031	load off
1	18007	
2	17760	
3	17560	

Test: Creep

Orient: ±45°

Spec. No: I5-5

Temp: 350°F(177°C)

Stress 12.89 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	11051	
0.017	13137	
0.10	14655	
0.25	15063	
0.50	15421	
1	15954	
2	17077	
3	gage failed	
502	no failure	
Recovery		

V378A

Test: Creep
Orient: ±45°
Spec. No: 13-3
Temp: 350°F (177°C)
Stress: 11.28 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6517	
0.017	7406	
0.10	7836	
0.25	8460	
0.50	9074	
1	9588	
2	10106	
3	10428	
4.5	10781	
5	10910	
6	11012	
24	11974	
144	13443	
240	14177	
336	14724	
361	14772	
408	15350	
527	16428	
Recovery		
0	10848	load off
0.5	8789	
1	8647	
2	8329	
6	7719	

Test: Creep
Orient: ±45°
Spec. No: 16-9
Temp: 350°F (177°C)
Stress: 11.28 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	gage failed	on loading
527	no failure	
Recovery		

Test: Creep
Orient: ±45°
Spec. No: 17-7
Temp: 350°F (177°C)
Stress 11.28 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	9133	
0.017	9387	
0.10	10115	
0.25	10622	
0.50	11084	
1	11526	
2	12028	
3	12348	
4.5	12654	
5	12842	
6	12968	
24	14481	
144	16692	
240	17379	
336	17857	
361	17994	
408	18178	
527	18634	
Recovery		
0	13297	load off
0.5	12559	
1	12456	
2	12257	
6	11882	

V378A

Test: Creep
Orient: ±45°
Spec. No: I3-1
Temp: 350°F (177°C)
Stress: 9.67 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4584	
0.017	4885	
0.10	5477	
0.25	5904	
0.50	6276	
1	6647	
4	7585	
6	7911	
7	8074	
8	8183	
30	9227	
120	9981	
222	10196	
320	10393	
456	10690	
476	10719	
510	10745	
Recovery		
0	6605	load off
0.5	6194	
1	6068	
1.5	6025	

Test: Creep
Orient: ±45°
Spec. No: I4-8
Temp: 350°F (177°C)
Stress: 9.67 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5188	
0.017	5588	
0.10	5918	
0.25	6153	
0.50	6310	
1	6526	
4	7127	
6	7406	
7	7501	
8	7568	
30	8673	
120	10282	
242	11046	
320	11600	
456	12769	
476	12967	
510	13172	
Recovery		
0	8565	load off
0.5	7995	
1	7839	
1.5	7781	

Test: Creep
Orient: ±45°
Spec. No: I5-3
Temp: 350°F (177°C)
Stress 9.67 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5397	
0.017	5488	
0.10	5580	
0.25	gage failed	
510	no failure	
Recovery		

V378A

Test: Creep
Orient: ±45°
Spec. No: I5-2
Temp: 450°F(232°C)
Stress: 11.95 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	gage failed on loading	
528	no failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: I6-5
Temp: 450°F(232°C)
Stress: 11.95 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	gage failed	
0.017	failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: I6-10
Temp: 450°F(232°C)
Stress 11.95 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7414	
0.017	7950	
0.10	8545	
0.25	9167	
0.50	9560	
1	10875	
1.5	gage failed	
191	failure	

Recovery

V378A

Test: Creep

Orient: ±45°

Spec. No: 15-8

Temp: 450°F(232°C)

Stress: 10.45 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7816	
0.017	9064	
0.10	10972	
0.25	11798	
0.50	12595	
1	13608	
2	14465	
3	15443	
4	15823	
5.5	16526	
6	16694	
23	gage failed	
503	no failure	
Recovery		

Test: Creep

Orient: ±45°

Spec. No: 17-4

Temp: 450°F(232°C)

Stress: 10.45 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7963	
0.017	9042	
0.10	12126	
0.25	gage failed	
503	no failure	
Recovery		

Test: Creep

Orient: ±45°

Spec. No: 18-2

Temp: 450°F(232°C)

Stress 10.45 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6257	
0.017	6737	
0.10	7206	
0.25	7506	
0.50	7732	
1	8012	
2	8277	
3	8591	
4	8706	
5.5	8975	
6	9040	
23	10093	
53	10924	
119	11735	
220	12359	
360	12841	
456	12912	
503	12970	
Recovery		
0	8653	load off
0.5	8055	
1	7944	
2	7834	

V378A

Test: Creep
Orient: 0/±45/90°
Spec. No: I25-6
Temp: 72°F(22°C)
Stress: 101.76 ksi 85% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	10076	
0.017	10087	
0.10	10110	
0.25	10128	
0.50	10138	
1	10150	
2	10160	
4	10175	
5	10176	
6.8	10180	
7.5	10184	
24	10203	
119	10253	
216	10237	
314	10232	
390	10213	
455	10230	
527	10218	
Recovery		
0	348	load off
0.5	288	
1	271	
5	224	

Test: Creep
Orient: 0/±45/90°
Spec. No: I28-5
Temp: 72°F(22°C)
Stress: 101.76 ksi 85% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failure	on loading
Recovery		

Test: Creep
Orient: 0/±45/90°
Spec. No: I35-2
Temp: 72°F(22°C)
Stress 101.76 ksi 85 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failure on	loading
Recovery		

V378A

Test: Creep

Orient: 0/+45/90°

Spec. No: I37-4

Temp: 72°F(22°C)

Stress: 95.20 ksi 79% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7672	
0.017	7698	
0.10	7716	
0.25	7733	
0.50	7742	
1	7750	
65	7838	
91	7850	
168	7845	
239	7856	
401	7879	
503	7850	
Recovery		
0	340	load off
0.5	302	
1	292	

Test: Creep

Orient: 0/+45/90°

Spec. No: I39-4

Temp: 72°F(22°C)

Stress: 95.20 ksi 79% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7862	
0.017	7881	
0.10	7903	
0.25	7918	
0.50	7926	
1	7935	
65	8012	
91	8020	
168	8043	
239	8056	
401	8075	
503	8045	
Recovery		
0	336	load off
0.5	291	
1	283	

Test: Creep

Orient: 0/+45/90°

Spec. No: I40-4

Temp: 72°F(22°C)

Stress 95.20 ksi 79% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7920	
0.017	7947	
0.10	7978	
0.25	8000	
0.50	8007	
1	8020	
65	8106	
91	8120	
168	8110	
239	8122	
401	8146	
503	8113	
Recovery		
0	300	load off
0.5	250	
1	245	

V378A

Test: Creep

Orient: 0/±45/90°

Spec. No: I29-5

Temp: 72°F(22°C)

Stress: 81.24 ksi 68% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7448	
0.017	7477	
0.10	7500	
0.25	7510	
0.50	7516	
1	7526	
5	7538	
6	7544	
29	7562	
78	7579	
149	7598	
311	7628	
503	7622	
Recovery		
0	321	load off
1	244	
2	230	
2.5	222	

Test: Creep

Orient: 0/±45/90°

Spec. No: I38-4

Temp: 72°F(22°C)

Stress: 81.24 ksi 68% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7300	
0.017	7325	
0.10	7344	
0.25	7354	
0.50	7358	
1	7371	
5	7380	
6	7387	
29	7407	
78	7425	
149	7443	
311	7472	
503	7465	
Recovery		
0	299	load off
1	222	
2	214	
2.5	211	

Test: Creep

Orient: 0/±45/90°

Spec. No: I14-3

Temp: 72°F(22°C)

Stress: 81.24 ksi 68% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7317	
0.017	7330	
0.10	7356	
0.25	7372	
0.50	7379	
1	7388	
2	7391	
3	7400	
4	7400	
5	7401	
6	7402	
7	7407	
78	7453	
240	7496	
432	7486	
505	7483	
Recovery		
0	271	load off
1	196	
1.5	188	
2	182	

V378A

Test: Creep

Orient: 0/±45/90°

Spec. No: I12-5

Temp: 350°F(177°C)

Stress: 84.86 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7651	
0.017	7761	
0.10	7663	
0.25	7693	
0.50	7698	
1	7683	
2	7688	
4	7666	
5	7699	
6.9	8434	
7.5	7668	
24	7682	
119	7806	
217	7805	
315	7733	
390	7683	
455	7661	
532	7614	
Recovery		
0	-85	load off
0.5	-111	
1	-116	
5	-134	

Test: Creep

Orient: 0/±45/90°

Spec. No: I36-3

Temp: 350°F(177°C)

Stress: 84.86 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6906	
0.017	6922	
0.10	6919	
0.25	6833	
0.50	6786	
1	6724	
2	6731	
4	6705	
5	6676	
6.9	6972	
7.5	6683	
24	6609	
119	6624	
217	7145	
315	7250	
390	7302	
455	7385	
532	7475	
Recovery		
0	-554	load off
0.5	-865	
1	-908	
5	-985	

Test: Creep

Orient: 0/±45/90°

Spec. No: I40-5

Temp: 350°F(177°C)

Stress 84.86 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7312	
0.017	7361	
0.10	7403	
0.25	7424	
0.50	7441	
1	7447	
2	7459	
4	7464	
5	7467	
6	7470	
7	7474	
26	7497	
145	7472	
222	7471	
295	7522	
361	7489	
455	7534	
530	7569	
Recovery		
0	364	load off
0.5	328	
1	322	
4	320	
5	316	

V378A

Test: Creep
Orient: 0/±45/90°
Spec. No: I13-5
Temp: 350°F(177°C)
Stress: 74.25 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7110	
0.017	7140	
0.10	gage failed	
507	no failure	

Recovery

Test: Creep
Orient: 0/±45/90°
Spec. No: I14-4
Temp: 350°F(177°C)
Stress: 74.25 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6793	
0.017	6824	
0.10	6830	
0.25	6809	
0.50	6817	
1	6809	
1.5	6811	
2	6807	
4	6807	
5	6803	
6	6794	
63	6748	
160	6678	
175	6732	
232	6621	
304	6605	
401	6588	
483	6579	
507	6561	

Recovery

0	-95	load off
0.5	-110	
1	-122	
2	-131	
3	-140	

Test: Creep
Orient: 0/+45/90°
Spec. No: I37-5
Temp: 350°F(177°C)
Stress 74.25 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6255	
0.017	6260	
0.10	6268	
0.25	6270	
0.50	6270	
1	6271	
1.5	6272	
2	6274	
4	6278	
5	6273	
6	6274	
63	6262	
160	6244	
175	6229	
232	6228	
304	6218	
401	6213	
483	6208	
507	6207	

Recovery

0	136	load off
0.5	93	
1	83	
2	72	
3	66	

HyE 1076J

Test: Creep
Orient: ±45°
Spec. No: J9-4
Temp: 72°F(22°C)
Stress: 20.05 ksi 90 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	11746	
0.017	12620	
0.10	13652	
0.25	14735	
0.42	failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: J7-3
Temp: 72°F(22°C)
Stress: 20.05 ksi 90% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failed on loading	

Recovery

Test: Creep
Orient: ±45°
Spec. No: J4-4
Temp: 72°F(22°C)
Stress 20.05 ksi 90 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	9860	
0.10	10773	
0.17	Failure	

Recovery

HyE 1076J

Test: Creep
Orient: ±45°
Spec. No: J7-2
Temp: 72°F(22°C)
Stress: 17.83 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6830	
0.017	7362	
0.10	7726	
0.25	7925	
0.50	8096	
1	8260	
3	8576	
4	8656	
5	8690	
6	8748	
46	9193	
142	9618	
240	9938	
310	10158	
407	10330	
504	10664	
Recovery		
0	3212	load off
0.5	2502	
1	2082	
2	1874	
3	1804	

Test: Creep
Orient: ±45°
Spec. No: J7-8
Temp: 72°F(22°C)
Stress: 17.83 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6470	
0.017	6718	
0.10	6984	
0.25	7134	
0.50	7261	
1	7388	
3	7624	
4	7692	
5	7712	
6	7760	
46	8108	
142	8480	
240	8718	
310	8873	
407	8996	
504	9242	
Recovery		
0	2386	load off
0.5	1678	
1	1539	
2	1382	
3	1328	

Test: Creep
Orient: ±45°
Spec. No: J10-3
Temp: 72°F(22°C)
Stress 17.83 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6126	
0.017	6318	
0.10	6545	
0.25	6684	
0.50	6801	
1	6922	
3	7146	
4	7208	
5	7225	
6	7268	
46	7600	
142	7926	
240	8118	
310	8258	
407	8370	
504	8586	
Recovery		
0	2107	load off
0.5	1494	
1	1374	
2	1230	
3	1172	

HyE 1076J

Test: Creep

Orient: +45°

Spec. No: J12-3

Temp: 72°F(22°C)

Stress: 15.60 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6229	
0.017	6370	
0.10	6586	
0.25	6716	
0.50	6806	
1	6900	
2	6996	
4	7094	
6	7142	
8	7172	
24	7395	
176	7732	
272	7881	
390	7996	
508	8115	
Recovery		
0	1907	Load off
0.5	1084	
1	1014	
2	944	
3	879	

Test: Creep

Orient: +45°

Spec. No: J8-8

Temp: 72°F(22°C)

Stress: 15.60 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6334	
0.017	6728	
0.10	6914	
0.25	7065	
0.50	7166	
1	7268	
2	7387	
4	7490	
6	7546	
8	7580	
24	7828	
176	8220	
272	8391	
390	8528	
508	8664	
Recovery		
0	2138	Load off
0.5	1352	
1	1268	
2	1193	
3	1114	

Test: Creep

Orient: +45°

Spec. No: J9-3

Temp: 72°F(22°C)

Stress 15.60 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6018	
0.017	6240	
0.10	6426	
0.25	6555	
0.50	6644	
1	6737	
2	6831	
4	6928	
6	6978	
8	7006	
24	7222	
176	7554	
272	7703	
390	7807	
508	7923	
Recovery		
0	1840	Load off
0.5	1122	
1	1053	
2	985	
3	918	

Test: Creep

Orient: ±45°

Spec. No: J6-4

Temp: 260°F(127°C)

Stress: 13.19 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6138	
0.017	6356	
0.10	7203	
0.25	7677	
0.50	8046	
1	8402	
2	8393	
66	10226	
116	gage failed	
501	no failure	

Recovery

Test: Creep

Orient: ±45°

Spec. No: J10-4

Temp: 260°F(127°C)

Stress: 13.19 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6111	
0.017	6257	
0.10	7247	
0.25	7831	
0.50	8321	
1	8771	
2	9222	
66	gage failed	
501	no failure	

Recovery

Test: Creep

Orient: ±45°

Spec. No: J12-4

Temp: 260°F(127°C)

Stress 13.19 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8561	
0.017	8810	
0.10	11295	
0.25	16967	
0.50	gage failed	
501	no failure	

Recovery

HyE 1076J

Test: Creep

Orient: ±45°

Spec. No: J3-7

Temp: 260°F (127°C)

Stress: 11.55 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7071	
0.017	gage failed	
7	failure	

Recovery

Test: Creep

Orient: ±45°

Spec. No: J5-3

Temp: 260°F (127°C)

Stress: 11.55 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4590	
0.017	4869	
0.10	5010	
0.25	5139	
0.50	5273	
1	5414	
2	5576	
3	5715	
4	5778	
5	5804	
25	6267	
100	6882	
203	7351	
246	7516	
270	7559	
395	7876	
446	8011	
508	8170	

Recovery

0	3887	Load off
0.5	3348	
1	3248	
2	3123	
3	3040	

Test: Creep

Orient: ±45°

Spec. No: J9-10

Temp: 260°F (127°C)

Stress 11.55 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5038	
0.017	5315	
0.10	5560	
0.25	5713	
0.50	5853	
1	6000	
2	6162	
3	6316	
4	6386	
5	6409	
25	6918	
100	7567	
174	7991	
246	8327	
270	8403	
395	8836	
446	9016	
508	9202	

Recovery

0	4463	Load off
0.5	3754	
1	3641	
2	3511	
3	3437	

HyE 1076J

Test: Creep
Orient: ±45°
Spec. No: J6-3
Temp: 260°F(127°C)
Stress: 9.90 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4754	
0.017	5107	
0.10	5592	
0.25	5691	
0.50	5728	
1	5768	
2	5832	
3	5870	
25	6114	
122	6448	
219	6657	
337	6846	
456	7044	
504	7101	
Recovery		
0	3021	Load off
0.5	2722	
1	2660	
2	2590	
3	2546	

Test: Creep
Orient: ±45°
Spec. No: J7-10
Temp: 260°F(127°C)
Stress: 9.90 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4128	
0.017	4263	
0.10	4632	
0.25	4918	
0.50	4911	
1	4996	
2	5115	
3	5184	
25	5551	
122	5945	
219	6146	
337	6332	
456	6491	
504	6546	
Recovery		
0	2934	Load off
0.5	2629	
1	2550	
2	2476	
3	2435	

Test: Creep
Orient: +45°
Spec. No: J8-3
Temp: 260°F(127°C)
Stress 9.90 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3932	
0.017	3990	
0.10	4503	
0.25	4782	
0.50	5010	
1	5269	
2	5587	
3	5793	
25	7081	
122	8799	
219	9779	
337	10653	
456	11462	
504	11740	
Recovery		
0	7984	Load off
0.5	7632	
1	7488	
2	7357	
3	7234	

HyE 1076J

Test: Creep
Orient: +45°
Spec. No: J3-3
Temp: 350°F(177°C)
Stress: 13.28 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	11149	
0.017	11960	
0.10	12634	
0.25	12956	
0.50	13069	
1	18850	
4	25946	
24	29040	
142	44824	
315	gage failed	
503	no failure	

Recovery

Test: Creep
Orient: +45°
Spec. No: J8-4
Temp: 350°F(177°C)
Stress: 13.28 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7146	
0.017	7563	
0.10	8201	
0.25	8324	
0.50	8367	
1	19288	
4	22202	
24	26287	
142	gage failed	
503	no failure	

Recovery

Test: Creep
Orient: +45°
Spec. No: J11-5
Temp: 350°F(177°C)
Stress 13.28 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8204	
0.017	8431	
0.10	9416	
0.25	9691	
0.50	9756	
1	gage failed	
503	no failure	

Recovery

HyE 1076J

Test: Creep
Orient: +45°
Spec. No: J3-8
Temp: 350°F(177°C)
Stress: 11.62 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	10676	
0.017	11179	
0.10	12510	
0.25	13308	
0.50	13813	
1	14531	
2	11002	
24	12677	
146	19627	
234	18960	
360	19330	
502	19410	
Recovery		
0	15759	Load off
0.5	15588	
1	15556	
2	15525	
3	15466	

Test: Creep
Orient: +45°
Spec. No: J4-7
Temp: 350°F(177°C)
Stress: 11.62 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	9641	
0.017	10195	
0.10	10942	
0.25	12141	
0.50	13052	
1	13815	
2	14531	
24	21027	
146	gage failed	
502	no failure	
Recovery		

Test: Creep
Orient: +45°
Spec. No: J10-9
Temp: 350°F(177°C)
Stress 11.62 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	11268	
0.017	11859	
0.10	13032	
0.25	14192	
0.50	14966	
1	16099	
2	16729	
24	gage failed	
502	no failure	
Recovery		

HyE 1076J

Test: Creep

Orient: +45°

Spec. No: J7-9

Temp: 350°F(177°C)

Stress: 9.96 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4895	
0.017	5373	
0.10	6350	
0.25	7038	
0.50	7554	
1	8195	
2	9087	
2.5	9388	
24	gage failed	
504	no failure	

Recovery

Test: Creep

Orient: +45°

Spec. No: J10-8

Temp: 350°F(177°C)

Stress: 9.96 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5792	
0.017	6289	
0.10	7821	
0.25	8631	
0.50	9303	
1	10145	
2	11142	
2.5	11376	
24	18847	
74	26763	
144	gage failed	
504	no failure	

Recovery

Test: Creep

Orient: +45°

Spec. No: J11-4

Temp: 350°F(177°C)

Stress 9.96 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5444	
0.017	5698	
0.10	6129	
0.25	6658	
0.50	7142	
1	7775	
2	8429	
2.5	8640	
24	14049	
74	19672	
144	23880	
241	28059	
339	gage failed	
504	no failure	

Recovery

HyE 1076J

Test: Creep
Orient: 0/+45/90°
Spec. No: J16-8
Temp: 72°F(22°C)
Stress: 93.46 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	8344	
0.017	8378	
0.10	8400	
0.25	8428	
0.50	8438	
1	8425	
65	8586	
114	8566	
233	8592	
406	8589	
500	8583	

Recovery

0	636	load off
1	572	
2	512	
3	508	

Test: Creep
Orient: 0/+45/90°
Spec. No: J13-7
Temp: 72°F(22°C)
Stress: 93.46 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failed on loading	

Recovery

Test: Creep
Orient: 0/+45/90°
Spec. No: J17-6
Temp: 72°F(22°C)
Stress 93.46 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failed on loading	

Recovery

HyE 1076J

Test: Creep
Orient: 0/±45/90°
Spec. No: J21-9
Temp: 72°F(22°C)
Stress: 81.77ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6446	
0.017	6469	
0.10	6486	
0.25	6493	
0.50	6496	
1	6500	
2	6499	
3	6500	
4	6496	
5	6534	
6	6516	
24	6535	
52	6534	
112	6561	
249	6585	
355	6598	
424	6613	
500	6620	
Recovery		
0	188	load off
0.5	160	
1	152	
5	134	

Test: Creep
Orient: 0/±45/90°
Spec. No: J13-9
Temp: 72°F(22°C)
Stress: 81.77 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6722	
0.017	6744	
0.10	6758	
0.25	6763	
0.50	6771	
1	6773	
2	6777	
4	6788	
5	6789	
6	6788	
7	6790	
24	6787	
127	6762	
223	6807	
341	6783	
465	6803	
508	6785	
Recovery		
0	78	load off
0.5	42	
1	32	
2	68	
3	61	

Test: Creep
Orient: 0/±45/90°
Spec. No: J15-10
Temp: 72°F(22°C)
Stress 81.77 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6760	
0.017	6784	
0.10	6810	
0.25	6822	
0.50	6830	
1	6840	
2	6843	
24	6850	
197	6852	
240	6856	
363	6892	
415	6896	
502	6887	
Recovery		
0	48	load off
0.5	16	
1	7	
2	7	
3	6	

HyE 1076J

Test: Creep

Orient: 0/+45/90°

Spec. No: J22-8

Temp: 72°F(22°C)

Stress: 70.09 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5573	
0.017	5593	
0.10	5620	
0.25	5627	
0.50	5633	
1	5634	
2	5631	
3	5627	
68	5577	
170	5655	
236	5673	
331	5688	
427	5663	
570	5691	
Recovery		
0	143	load off
0.5	111	
1	108	
2	97	
3	92	

Test: Creep

Orient: 0/+45/90°

Spec. No: J13-10

Temp: 72°F(22°C)

Stress: 70.09 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6030	
0.017	6053	
0.10	6074	
0.25	6082	
0.50	6088	
1	6094	
2	6097	
3	6094	
79	6079	
170	6166	
236	6184	
331	6202	
427	6177	
571	6214	
Recovery		
0	207	load off
0.5	164	
1	155	
2	146	
3	140	

Test: Creep

Orient: 0/+45/90°

Spec. No: J20-10

Temp: 72°F(22°C)

Stress 70.09 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6826	
0.017	6868	
0.10	6890	
0.25	6904	
0.50	6915	
1	6921	
2	6933	
3	6934	
24	6957	
123	6988	
259	7028	
363	7056	
435	7070	
500	7080	
Recovery		
0	254	
0.5	217	
1	207	
5	192	

HyE 1076J

Test: Creep

Orient: 0/±45/90°

Spec. No: J15-7

Temp: 260°F(127°C)

Stress: 96.06 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7702	
0.017	7710	
0.10	7694	
0.25	7700	
0.50	7692	
1	7693	
30	7654	
100	7627	
130.4	failed	

Recovery

Test: Creep

Orient: 0/±45/90°

Spec. No: J16-9

Temp: 260°F(127°C)

Stress: 96.06 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6433	
0.017	6435	
0.10	6435	
0.25	6425	
0.50	6423	
1	6415	
100	6401	
218	6411	
313	6423	
493	6432	
506	6436	

Recovery

0	-230	load off
0.5	-230	
1	-204	
2	-206	
3	-182	

Test: Creep

Orient: 0/±45/90°

Spec. No: J16-10

Temp: 260°F(127°C)

Stress 96.06 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8159	
0.017	8163	
0.10	8170	
0.25	8179	
0.50	8181	
1	8183	
30	8203	
100	8220	
130.4	failed	

Recovery

HyE 1076J

Test: Creep
Orient: 0/±45/90°
Spec. No: J20-8
Temp: 260°F(127°C)
Stress: 84.05 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6599	
0.017	6599	
0.10	6599	
0.25	6593	
0.50	6594	
1	6595	
3	6585	
4	6584	
5	6583	
79	6562	
175	6553	
293	6567	
412	6564	
507	6562	
Recovery		
0	7	load off
1	-54	
2	-55	
3	-66	

Test: Creep
Orient: 0/±45/90°
Spec. No: J21-10
Temp: 260°F(127°C)
Stress: 84.05 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7263	
0.017	7235	
0.10	7290	
0.25	7303	
0.50	7306	
1	7313	
3	7308	
4	7305	
5	7303	
79	7291	
175	7287	
293	7312	
412	7312	
507	7307	
Recovery		
0	30	load off
1	-12	
2	- 8	
3	- 4	

Test: Creep
Orient: 0/+45/90°
Spec. No: J22-9
Temp: 260°F(127°C)
Stress 84.05 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6458	
0.017	6459	
0.10	6455	
0.25	6453	
0.50	6455	
1	6451	
2	6450	
3	6451	
4	6453	
5	6453	
24	6443	
96	6436	
199	6428	
271	6432	
367	6451	
433	6475	
504	6458	
Recovery		
0	-40	load off
0.5	-63	
1	-69	
2.5	-76	
3	-72	

HyE 1075J

Test: Creep
Orient: 0/±45/90°
Spec. No: J14-9
Temp: 260°F(127°C)
Stress: 72.04 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5521	
0.017	5525	
0.10	5539	
0.25	5544	
0.50	5554	
1	5561	
2	5561	
23	5569	
98	5589	
163	5601	
266	5628	
331	5637	
426	5654	
522	5671	
Recovery		
0	139	load off
0.5	124	
1	121	
2	115	
3	111	

Test: Creep
Orient: 0/±45/90°
Spec. No: J14-10
Temp: 260°F(127°C)
Stress: 72.04 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6912	
0.017	6914	
0.10	7061	
0.25	7048	
0.50	7051	
1	7044	
2	7035	
23	7014	
98	7025	
163	7033	
266	7043	
331	7051	
426	7058	
522	7077	
Recovery		
0	45	load off
0.5	- 6	
1	-13	
2	-20	
3	-26	

Test: Creep
Orient: 0/±45/90°
Spec. No: J14-8
Temp: 260°F(127°C)
Stress 72.04 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5877	
0.017	5884	
0.10	5881	
0.25	5881	
0.50	5884	
1	5880	
2	5875	
3	5871	
24	5860	
99	5859	
171	5860	
267	5868	
333	5875	
434	5884	
500	5890	
Recovery		
0	-9	load off
0.5	-28	
1	-33	
2	-43	

HyE 1076J

Test: Creep

Orient: 0/±45/90°

Spec. No: J20-7

Temp: 350°F(177°C)

Stress: 94.49 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	7839	
0.017	7841	
0.10	7842	
0.25	7844	
0.50	7856	
1	7856	
2	7868	
3	7876	
4	7880	
5	7886	
6	7902	
24	7892	
97	7657	
163	7667	
261	7675	
380	7791	
411	7823	
431	7834	
503	8048	
Recovery		
0	90	load off
1	5	
2	-13	
3	-44	

Test: Creep

Orient: 0/±45/90°

Spec. No: J17-8

Temp: 350°F(177°C)

Stress: 94.49 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failed on	loading
Recovery		

Test: Creep

Orient: 0/±45/90°

Spec. No: J21-7

Temp: 350°F(177°C)

Stress 94.49 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	8064	
0.017	8064	
0.10	8080	
0.25	8084	
0.50	8088	
1	8086	
52	8130	
163	8178	
234	8184	
332	8204	
402	8211	
502	8220	
Recovery		
0	0	load off
1	-53	
2	-76	
3	-83	

HyE 1076J

Test: Creep
Orient: 0/±45/90°
Spec. No: J16-7
Temp: 350°F(177°C)
Stress: 82.68 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6601	
0.017	6634	
0.10	6646	
0.25	6650	
0.50	6654	
1	6666	
2	6650	
3	6646	
24	6591	
75	6648	
315	7039	
411	7076	
500	7095	
Recovery		
0	321	load off
0.5	26[illegible]	
1	236	
2	227	
3	216	

Test: Creep
Orient: 0/±45/90°
Spec. No: J17-7
Temp: 350°F(177°C)
Stress: 82.68 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6217	
0.017	6227	
0.10	6231	
0.25	6245	
0.50	6270	
1	6300	
2	6318	
3	6318	
24	6554	
75	6739	
315	6872	
411	6992	
500	6894	
Recovery		
0	654	load off
0.5	517	
1	484	
2	477	
3	462	

Test: Creep
Orient: 0/±45/90°
Spec. No: J13-8
Temp: 350°F(177°C)
Stress 82.68 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5475	
0.017	5499	
0.10	5568	
0.25	5657	
0.50	5692	
1	5706	
2	5733	
24	5946	
90	6147	
215	6206	
384	6157	
521	6124	
Recovery		
0	97	load off
0.5	19	
1	12	
2	12	
3	3	

HyE 1076J

Test: Creep
Orient: 0/+45/90°
Spec. No: J15-9
Temp: 350°F(177°C)
Stress: 70.87 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4960	
0.017	4995	
0.10	5004	
0.25	5019	
0.50	4911	
1	4927	
3	4963	
4	4978	
5	4995	
6	5011	
24	5214	
99	5396	
196	5423	
294	5424	
362	5421	
431	5414	
504	5394	
Recovery		
0	231	load off
0.5	220	
3	193	
4	187	

Test: Creep
Orient: 0/+45/90°
Spec. No: J22-10
Temp: 350°F(177°C)
Stress: 70.87 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5959	
0.017	5979	
0.10	6004	
0.25	6008	
0.50	6528	
1	6562	
3	6580	
4	6584	
5	6586	
6	6587	
24	6659	
99	6978	
196	7205	
294	7328	
362	7373	
431	7403	
504	7398	
Recovery		
0	797	load off
0.5	718	
3	673	
4	652	

Test: Creep
Orient: 0/+45/90°
Spec. No: J20-9
Temp: 350°F(177°C)
Stress 70.87 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5489	
0.017	5491	
0.10	5500	
0.25	5490	
0.50	5483	
1	5476	
3	5457	
4	5457	
6	5458	
25	5475	
148	5779	
267	5839	
364	5862	
462	5877	
527	5877	
Racovery		
0	327	load off
0.5	298	
1	295	
2	286	
4	278	

Test: Creep
Orient: +45°
Spec. No: K4-9
Temp: 72°F(22°C)
Stress: 13.22 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4932	
0.017	5134	
0.10	5357	
0.25	5486	
0.50	5601	
1	5718	
2	5840	
3	5910	
43	6406	
218	6878	
335	7062	
431	7170	
504	7244	
Recovery		
0	2232	load off
0.5	1660	
1	1562	
2	1454	

Test: Creep
Orient: +45°
Spec. No: K8-8
Temp: 72°F(22°C)
Stress: 13.22 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4968	
0.017	5107	
0.10	5347	
0.25	5468	
0.50	5590	
1	5706	
2	5828	
3	5900	
43	6439	
218	6965	
335	7170	
431	7289	
504	7366	
Recovery		
0	2258	load off
0.5	1668	
1	1557	
2	1448	

Test: Creep
Orient: +45°
Spec. No: K11-8
Temp: 72°F(22°C)
Stress 13.22 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5488	
0.015	5580	
0.10	5910	
0.25	6048	
0.50	6198	
1	6337	
2	6485	
3	6569	
43	7186	
218	7800	
335	8041	
431	8180	
504	8269	
Recovery		
0	2774	load off
0.5	2003	
1	1867	
2	1736	

6535-1

Test: Creep
Orient: ±45°
Spec. No: K8-6
Temp: 72°F(22°C)
Stress: 11.57 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4246	
0.017	4498	
0.10	4626	
0.25	4731	
0.50	4831	
1	4890	
2	4968	
3	5029	
25	5316	
91	5562	
194	5772	
267	5874	
351	6015	
434	6101	
503	6160	
Recovery		
0	1530	load off
0.5	1038	
1	958	
2	901	
3	858	

Test: Creep
Orient: ±45°
Spec. No: K10-9
Temp: 72°F(22°C)
Stress: 11.57 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4456	
0.017	4627	
0.10	4784	
0.25	4897	
0.50	5010	
1	5076	
2	5165	
3	5232	
25	5555	
91	5828	
194	6089	
267	6214	
351	6371	
434	6465	
503	6535	
Recovery		
0	1757	load off
0.5	1200	
1	1107	
2	1050	
3	1000	

Test: Creep
Orient: ±45°
Spec. No: K11-6
Temp: 72°F(22°C)
Stress: 11.57 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4582	
0.017	4690	
0.10	4872	
0.25	4977	
0.50	5097	
1	5159	
2	5250	
3	5315	
25	5639	
91	5910	
194	6146	
267	6258	
351	6407	
434	6500	
503	6572	
Recovery		
0	1885	load off
0.5	1265	
1	[illegible]	
2	[illegible]	
3	1053	

6535-1

Test: Creep
Orient: ±45°
Spec. No: K3-2
Temp: 72°F(22°C)
Stress: 9.92 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3417	
0.017	3550	
0.10	3632	
0.25	3700	
0.50	3764	
1	3803	
3	3858	
4	3884	
5	3966	
47	4188	
195	4373	
222	4390	
312	4490	
456	4584	
502	4610	
Recovery		
0	1224	load off
0.5	918	
1	868	
2	799	
5	738	

Test: Creep
Orient: ±45°
Spec. No: K3-3
Temp: 72°F(22°C)
Stress: 9.92 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3310	
0.017	3399	
0.10	3466	
0.25	3520	
0.50	3572	
1	3607	
3	3650	
4	3674	
5	3748	
47	3939	
195	4108	
222	4120	
312	4205	
456	4286	
502	4327	
Recovery		
0	1059	load off
0.5	835	
1	756	
2	697	
5	646	

Test: Creep
Orient: ±45°
Spec. No: K3-4
Temp: 72°F(22°C)
Stress 9.92 ksi 60% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3528	
0.017	3626	
0.10	3700	
0.25	3767	
0.50	3832	
1	3872	
3	3927	
4	3954	
5	4034	
47	4267	
195	4450	
222	4468	
312	4565	
456	4660	
502	4690	
Recovery		
0	1177	load off
0.5	900	
1	851	
2	784	
5	725	

Test: Creep
Orient: ±45°
Spec. No: K6-8
Temp: 260°F(127°C)
Stress: 12.45 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5213	
0.017	5656	
0.10	6094	
0.25	6369	
0.50	6567	
1	6783	
2	6981	
3	7173	
43	8472	
253	12829	
308	gage failed	
500	no failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: K6-9
Temp: 260°F(127°C)
Stress: 12.45 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6456	
0.017	7148	
0.10	7743	
0.25	8148	
0.50	8610	
1	9021	
2	9719	
4	10429	
5	10648	
7	10976	
24	12702	
43	gage failed	
500	no failure	

Recovery

Test: Creep
Orient: ±45°
Spec. No: K6-10
Temp: 260°F(127°C)
Stress 12.45 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5197	
0.017	5484	
0.10	6131	
0.25	6330	
0.50	6514	
1	6696	
2	6979	
4	7339	
5	7458	
7	7647	
24	8606	
54	failure	

Recovery

6535-1

Test: Creep
Orient: ±45°
Spec. No: K4-8
Temp: 260°F(127°C)
Stress: 10.89 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	4549	
0.017	4944	
0.10	5192	
0.25	5364	
0.50	5440	
1.5	5607	
2.5	5670	
3	5704	
5	5806	
7	5972	
8	5880	
24	6113	
127	6569	
223	6803	
342	7016	
459	7201	
508	7275	
Recovery		
0	2863	load off
0.5	2333	
1	2179	
2	2077	

Test: Creep
Orient: ±45°
Spec. No: K7-10
Temp: 260°F(127°C)
Stress: 10.89 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5382	
0.017	5673	
0.10	5993	
0.25	6147	
0.50	6347	
1	6536	
6	7122	
7	7175	
69	8557	
174	9594	
246	10348	
339	11644	
414	14254	
431	failed	
Recovery		

Test: Creep
Orient: ±45°
Spec. No: K10-7
Temp: 260°F(127°C)
Stress 10.89 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	4734	
0.017	4925	
0.10	5413	
0.25	5730	
0.50	5830	
1.5	6025	
2.5	6121	
3	6154	
5	6274	
7	6363	
8	6389	
24	6703	
127	7477	
223	7919	
342	8385	
459	8722	
508	8857	
Recovery		
0	4543	load off
0.5	4019	
1	3861	
2	3727	

Test: Creep
Orient: ±45°
Spec. No: K4-10
Temp: 260°F(127°C)
Stress: 9.44 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3405	
0.017	3597	
0.10	3719	
0.25	3898	
0.50	3929	
1	3996	
3	4129	
4	4173	
73	4667	
170	4890	
245	5008	
337	5141	
458	5282	
504	5315	
Recovery		
0	17[illegible]4	load off
0.5	1623	
1	1577	
2	1515	

Test: Creep
Orient: ±45°
Spec. No: K10-8
Temp: 260°F(127°C)
Stress: 9.44 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3346	
0.017	3507	
0.10	3635	
0.25	3771	
0.50	3915	
1	3921	
3	4080	
4	4126	
73	4746	
170	5078	
245	5222	
337	5403	
458	5597	
504	5652	
Recovery		
0	2173	load off
0.5	2052	
1	1998	
2	1953	

Test: Creep
Orient: ±45°
Spec. No: K10-10
Temp: 260°F(127°C)
Stress 9.44 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	3630	
0.017	3753	
0.10	3966	
0.25	4103	
0.50	4178	
1	4315	
3	4522	
4	4595	
73	5473	
170	5889	
245	6125	
337	6435	
458	6801	
504	6975	
Recovery		
0	4211	load off
0.5	4059	
1	4054	
2	4049	

Test: Creep
Orient: ±45°
Spec. No: K3-1
Temp: 350°F(177°C)
Stress: 11.54 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5574	
0.017	6329	
0.10	7338	
0.25	8092	
0.50	8571	
1	9198	
2	9869	
3	10402	
5.5	11136	
7	11456	
8	11687	
31	14284	
79	16567	
144	18440	
247	20764	
315	22307	
415	23965	
504	25513	
Recovery		
0	20250	load off
0.5	17465	
1	16962	
3	16385	
5	15865	

Test: Creep
Orient: ±45°
Spec. No: K5-7
Temp: 350°F(177°C)
Stress: 11.54 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	7114	
0.017	7665	
0.10	8900	
0.25	gage failed	
504	no failure	
Recovery		

Test: Creep
Orient: ±45°
Spec. No: K5-8
Temp: 350°F(177°C)
Stress 11.54 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6705	
0.017	7090	
0.10	7904	
0.25	12756	
0.50	19949	
1	24217	
2	gage failed	
504	no failure	
Recovery		

Test: Creep
Orient: ±45°
Spec. No: K7-8
Temp: 350°F(177°C)
Stress: 9.89 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5513	
0.017	5895	
0.10	7346	
0.25	7923	
0.50	8631	
1	9386	
2	10357	
5	11626	
79	18644	
174	22616	
247	24250	
343	26175	
414	27291	
508	28737	
Recovery		
0	24736	load off
0.5	23938	
1	23579	
2	23429	

Test: Creep
Orient: ±45°
Spec. No: K8-7
Temp: 350°F(177°C)
Stress: 9.89 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5374	
0.017	5646	
0.10	7178	
0.25	7906	
0.50	8628	
1	9411	
2	10321	
5	11987	
79	21383	
174	25911	
247	28046	
343	30486	
414	32217	
508	gage failed	
Recovery		

Test: Creep
Orient: ±45°
Spec. No: K9-9
Temp: 350°F(177°C)
Stress 9.89 ksi 60 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6794	
0.017	7194	
0.10	7792	
0.25	8235	
0.50	14336	
1	14763	
2	14859	
5	gage failed	
508	no failure	
Recovery		

6535-1

Test: Creep
Orient: ±45°
Spec. No: K11-7
Temp: 350°F(177°C)
Stress: 8.24 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	3668	
0.017	3954	
0.10	4738	
0.25	5258	
0.50	5670	
1	6148	
3	7073	
4	7474	
73	14048	
170	16375	
215	17577	
263	17850	
337	18891	
458	20324	
504	21020	

Recovery

0	17993	load off
0.5	17430	
1	17275	
2	17124	

Test: Creep
Orient: ±45°
Spec. No: K7-9
Temp: 350°F(177°C)
Stress: 8.24 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
Specimen overheated before test was run.		

Recovery

Test: Creep
Orient: ±45°
Spec. No: K9-10
Temp: 350°F(177°C)
Stress 8.24 ksi 50 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
Specimen failed on loading.		

Recovery

6535-1

Test: Creep

Orient: See below

Spec. No: K24-4

Temp: 72°F(22°C)

Stress: 72.70 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6278	
0.017	6302	
0.10	6316	
0.25	6323	
0.50	6327	
1	6330	
3	6335	
5	6335	
6	6335	
71	6366	
175	6382	
240	6404	
342	6399	
406	6420	
502	6426	
Recovery		
0	158	load off
0.5	122	
1	115	
2	102	

[0,+45,-45,0,0,-45,+45,0,90,0]$_s$

Test: Creep

Orient: See below

Spec. No: K26-2

Temp: 72°F(22°C)

Stress: 72.70 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failure on loading	
Recovery		

Test: Creep

Orient: See below

Spec. No: K24-8

Temp: 72°F(22°C)

Stress 72.70 ksi 80 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6353	
0.017	6380	
0.10	6401	
0.25	6410	
0.50	6418	
1	6423	
2	6428	
25	6452	
91	6478	
194	6490	
260	6514	
362	6511	
427	6534	
501	6532	
Recovery		
0	237	load off
0.5	193	
1	188	
3	183	
4	177	

6535-1

Test: Creep
Orient: See below
Spec. No: K25-5
Temp: 72°F (22°C)
Stress: 63.62 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5346	
0.017	5364	
0.10	5387	
0.25	5394	
0.50	5400	
1	5400	
3	5406	
4	5405	
5	5406	
6	5405	
24	5422	
54	5420	
119	5444	
221	5456	
335	5484	
455	5489	
503	5482	
Recovery		
0	140	load off
0.5	107	
1	100	
2	90	
4	83	

Test: Creep
Orient: See below
Spec. No: K25-3
Temp: 72°F (22°C)
Stress: 63.62 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5408	
0.017	5431	
0.10	5454	
0.25	5458	
0.50	5459	
1	5461	
2	5458	
4	5457	
5	5452	
7	5449	
24	5465	
55	5453	
120	5468	
222	5475	
336	5497	
456	5503	
504	5496	
Recovery		
0	90	load off
0.5	70	
1	64	
2	57	
4	54	

Test: Creep
Orient: See below
Spec. No: K26-8
Temp: 72°F (22°C)
Stress: 63.62 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5286	
0.017	5295	
0.10	5450	
0.25	5455	
0.50	5457	
1	5457	
2	5454	
4	5453	
5	5452	
7	5449	
24	5463	
55	5456	
120	5473	
222	5484	
336	5505	
456	5510	
504	5505	
Recovery		
0	167	load off
0.5	142	
1	136	
2	126	
4	123	

$[0,+45,-45,0,0,-45,+45,0,90,0]_s$

6535-1

Test: Creep

Orient: See below

Spec. No: K35-2

Temp: 72°F(22°C)

Stress: 73.22 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6413	
0.017	6435	
0.10	6456	
0.25	6466	
0.50	6470	
1	6472	
2	6476	
3	6478	
25	6499	
98	6518	
171	6519	
267	6472	
338	6465	
434	6466	
552	6482	
Recovery		
0	126	load off
0.5	73	
1	59	
2	56	
3	50	

Test: Creep

Orient: See below

Spec. No: K36-4

Temp: 72°F(22°C)

Stress: 73.22 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failure on loading	
Recovery		

Test: Creep

Orient: See below

Spec. No: K34-1

Temp: 72°F(22°C)

Stress 73.22 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6523	
0.017	6546	
0.10	6566	
0.25	6578	
0.50	6582	
1	6587	
3	6592	
4	6591	
5	6591	
5	6590	
24	6617	
100	6624	
270	6577	
341	6581	
437	6594	
506	6597	
Recovery		
0	136	load off
0.5	72	
1	63	
2	57	
3	52	

$[0,+45,-45,0,0,-45,+45,0]_s$

6535-1

Test: Creep
Orient: See below
Spec. No: K34-7
Temp: 72°F(22°C)
Stress: 64.07 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5596	
0.017	5614	
0.10	5632	
0.25	5642	
0.50	5650	
1	5653	
2	5658	
4	5670	
5	5664	
7	5664	
25	5683	
103	5686	
271	5710	
367	5704	
438	5706	
510	5707	
Recovery		
0	60	load off
0.5	31	
1	25	
2	21	

Test: Creep
Orient: See below
Spec. No: K35-10
Temp: 72°F(22°C)
Stress: 64.07 ksi 70% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5717	
0.017	5746	
0.10	5767	
0.25	5780	
0.50	5786	
1	5792	
2	5797	
4	5808	
5	5806	
7	5802	
30	5818	
103	5828	
271	5851	
367	5836	
438	5837	
510	5838	
Recovery		
0	94	load off
0.5	53	
1	47	
2	40	

Test: Creep
Orient: See below
Spec. No: K36-6
Temp: 72°F(22°C)
Stress 64.07 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5604	
0.017	5782	
0.10	5816	
0.25	5826	
0.50	5833	
1	5839	
2	5844	
4	5852	
5	5852	
7	5848	
30	5862	
103	5872	
271	5897	
367	5882	
438	5884	
510	5885	
Recovery		
0	137	load off
0.5	90	
1	80	
2	75	

$[0,+45,-45,0,0,-45,+45,0]_s$

6535-1

Test: Creep
Orient: See below
Spec. No: K38-4
Temp: 72°F(22°C)
Stress: 77.83 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	6404	
0.017	6422	
0.10	6437	
0.25	6443	
0.50	6448	
1	6453	
2	6460	
3	6456	
48	6482	
125	6492	
219	6501	
265	6475	
461	6482	
487	6502	
506	6462	
Recovery		
0	73	load off
0.5	39	
1	39	
2	39	

Test: Creep
Orient: See below
Spec. No: K39-5
Temp: 72°F(22°C)
Stress: 77.83 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	failure on loading	
Recovery		

Test: Creep
Orient: See below
Spec. No: K37-10
Temp: 72°F(22°C)
Stress 77.83 ksi 80% ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	6488	
0.017	6506	
0.10	6522	
0.25	6530	
0.50	6537	
1	6542	
3	6552	
4	6556	
5	6556	
51	6579	
127	6592	
222	6606	
342	6583	
464	6588	
481	6606	
505	6574	
Recovery		
0	117	
0.5	60	
1	56	
2	60	

$[0,90,-45,-45,0,0,-45,+45,0,0]_s$

6535-1

Test: Creep
Orient: See below
Spec. No: K38-7
Temp: 72°F(22°C)
Stress: 68.10 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μ in/in)	Remarks
0	5746	
0.017	5765	
0.10	5778	
0.25	5783	
0.50	5788	
1	5794	
2	5799	
3	5799	
71	5816	
167	5826	
243	5838	
338	5844	
408	5821	
503	5834	
Recovery		
0	71	load off
0.5	40	
1	32	
2	26	

Test: Creep
Orient: See below
Spec. No: K39-3
Temp: 72°F(22°C)
Stress: 68.10 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5406	
0.017	5565	
0.10	5574	
0.25	5579	
0.50	5585	
1	5590	
2	5590	
3	5590	
71	5588	
167	5596	
243	5607	
338	5610	
408	5590	
503	5600	
Recovery		
0	60	load off
0.5	31	
1	25	
2	18	

Test: Creep
Orient: See below
Spec. No: K37-5
Temp: 72°F(22°C)
Stress 68.10 ksi 70 % ult.

Elap. Time (hrs.)	Accum. Strain (μin/in)	Remarks
0	5811	
0.017	5819	
0.10	5833	
0.25	5841	
0.50	5848	
1	5854	
2	5859	
3	5862	
71	5880	
167	5889	
243	5901	
338	5909	
408	5684	
503	5894	
Recovery		
0	114	load off
0.5	86	
1	78	
2	70	

$[0,90,+45,-45,0,0,-45,+45,0,0]_s$

APPENDIX K
THERMAL EXPANSION DATA

All of the thermal expansion data generated during this program are presented in this appendix. In addition, a typical thermal expansion curve is included at the end of the section. The procedure for computing coefficient of thermal expansion from such a curve is detailed in Paragraph 3.5.10. These data are summarized in Paragraphs 4.1 through 4.6.

Test: Coefficient of Thermal Expansion

Materials: Aluminum Standard

Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Variation from Literature Value Remarks
		50	11.59	4.4%
		212	12.29	6.2%
		392	13.00	4.5%
		572	13.16	7.1%

This aluminum standard and its α values, was supplied by Perkin Elmer, but is not traceable to NBS.

Test: Coefficient of Thermal Expansion				
Materials: T300/AFR800				
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
FB1-5	0°	-67	-0.083	
FB2-6	0°	-67	-0.036	
FB3-3	0°	-67	-0.135	
Avg.			-0.085	
FB1-7	0°	72	-0.358	
FB2-4	0°	72	-0.352	
FB3-4	0°	72	-0.403	
Avg.			-0.371	
FB1-1	0°	260	-0.130	
FB2-1	0°	260	-0.125	
FB3-1	0°	260	-0.155	
Avg.			-0.137	
FB1-4	0°	350	-0.109	
FB2-2	0°	350	-0.327	
FB3-2	0°	350	-0.170	
Avg.			-0.202	
FA1-6	90°	-67	12.18	
FA1-8	90°	-67	11.96	
FA2-4	90°	-67	14.47	
Avg.			12.87	
FA1-7	90°	72	13.60	
FA1-9	90°	72	13.32	
FA2-5	90°	72	13.72	
Avg.			13.55	

Test: Coefficient of Thermal Expansion				
Materials: T300/AFR800				
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
FA1-1	90°	260	12.85	
FA1-3	90°	260	14.79	
FA2-3	90°	260	15.70	
Avg.			14.45	
FA1-2	90°	350	17.03	
FA1-5	90°	350	17.38	
FA2-2	90°	350	16.31	
Avg.			16.91	
FC1-3	±45°	-67	2.378	
FC2-3	±45°	-67	2.905	
FC3-3	±45°	-67	2.599	
Avg.			2.627	
FC1-4	±45°	72	2.440	
FC2-4	±45°	72	2.732	
FC3-4	±45°	72	2.171	
Avg.			2.448	
FC1-1	±45°	260	2.939	
FC2-1	±45°	260	2.988	
FC3-1	±45°	260	2.508	
Avg.			2.812	
FC1-2	±45°	350	3.416	
FC2-2	±45°	350	3.529	
FC3-2	±45°	350	2.768	
Avg.			3.238	

Test: Coefficient of Thermal Expansion				
Materials: SiC/5506				
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
G10-A	0°	-67	1.38	
G10-B	0°	-67	1.34	
G10-C	0°	-67	1.29	
Avg.			1.34	
G10-A	0°	72	1.28	
G10-B	0°	72	1.52	
G10-C	0°	72	1.47	
Avg.			1.56	
G10-A	0°	260	2.34	
G10-B	0°	260	1.76	
G10-C	0°	260	1.92	
Avg.			2.01	
G10-A	0°	350	2.70	
G10-B	0°	350	2.12	
G10-C	0°	350	1.88	
Avg.			2.23	
G10-D	90°	-67	7.78	
G10-E	90°	-67	8.11	
G10-F	90°	-67	7.78	
Avg.			7.89	
G10-D	90°	72	9.61	
G10-E	90°	72	9.67	
G10-F	90°	72	9.39	
Avg.			9.56	

Test: Coefficient of Thermal Expansion				
Materials: SiC/5506				
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
G10-D	90°	260	19.4	
G10-E	90°	260	20.2	
G10-F	90°	260	16.9	
Avg.			18.8	
G10-D	90°	350	38.2	
G10-E	90°	350	41.4	
G10-F	90°	350	33.9	
Avg.			37.8	
G15-A	±45°	-67	2.86	
G15-B	±45°	-67	2.92	
G17-A	±45°	-67	2.73	
Avg.			2.83	
G15-A	±45°	72	3.31	
G15-B	±45°	72	3.47	
G17-A	±45°	72	3.22	
Avg.			3.33	
G15-A	±45°	260	3.56	
G15-B	±45°	260	4.10	
G17-C	±45°	260	2.89	
Avg.			3.52	
G15-A	±45°	350	4.12	
G15-B	±45°	350	5.14	
G17-A	±45°	350	2.94	
Avg.			4.07	

Test: Coefficient of Thermal Expansion				
Materials: HyE 2034D				
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
H32-2	0°	-67	-1.00	
H32-3	0°	-67	-1.29	
H32-1	0°	-67	-1.38	
Avg.			-1.22	
H32-2	0°	72	-1.55	
H32-3	0°	72	-1.36	
H32-1	0°	72	-1.70	
Avg.			-1.54	
H32-1	0°	260	-1.62	
H32-2	0°	260	-1.65	
H32-3	0°	260	-1.57	
Avg.			-1.61	
H32-1	0°	350	-1.43	
H32-2	0°	350	-1.92	
H32-3	0°	350	-2.48	
Avg.			-1.94	
H32-4	90°	-67	26.5	
H32-5	90°	-67	26.6	
H32-6	90°	-67	28.2	
Avg.			27.1	
H32-4	90°	72	32.0	
H32-5	90°	72	29.6	
H32-6	90°	72	30.3	
Avg.			30.6	

Test: Coefficient of Thermal Expansion				
Materials: HyE 2034D				
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
H32-4	90°	260	39.4	
H32-5	90°	260	37.1	
H32-6	90°	260	42.2	
Avg.			39.6	
H32-4	90°	350	58.7	
H32-5	90°	350	54.7	
H32-6	90°	350	59.9	
Avg.			57.8	
H34-1	45°	-67	-0.463	
H34-2	45°	-67	-0.320	
H34-3	45°	-67	-0.0127	
Avg.			-0.265	
H34-1	45°	72	-0.517	
H34-2	45°	72	-0.475	
H34-3	45°	72	-0.221	
Avg.			-0.404	
H34-1	45°	260	-0.557	
H34-2	45°	260	-0.694	
H34-3	45°	260	-0.662	
Avg.			-0.638	
H34-1	45°	350	-0.674	
H34-2	45°	350	-0.923	
H34-3	45°	350	-1.06	
Avg.			-0.886	

Test: Coefficient of Thermal Expansion				
Materials: T300/V378A				
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
I43-1	0°	-67	0.145	
I43-2	0°	-67	0.099	
I43-3	0°	-67	0.415	
Avg.			0.217	
I43-1	0°	72	-0.101	
I43-2	0°	72	-0.162	
I43-3	0°	72	-0.556	
Avg.			-0.273	
I43-1	0°	350	-0.108	
I43-2	0°	350	-0.219	
I43-3	0°	350	-0.281	
Avg.			-0.203	
I43-1	0°	450	-0.148	
I43-2	0°	450	-0.217	
I43-3	0°	450	-0.370	
Avg.			-0.245	
I44-1	45°	-67	4.27	
I44-2	45°	-67	3.80	
I44-3	45°	-67	3.86	
Avg.			3.98	
I44-1	45°	72	2.96	
I44-2	45°	72	2.84	
I44-3	45°	72	3.12	
Avg.			2.97	

Test: Coefficient of Thermal Expansion				
Materials: T300/V378A				
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
I44-1	45°	350	4.00	
I44-2	45°	350	2.89	
I44-3	45°	350	4.49	
Avg.			3.79	
I44-1	45°	450	3.86	
I44-2	45°	450	2.63	
I44-3	45°	450	4.65	
Avg.			3.71	
I43-4	90°	-67	29.5	
I43-5	90°	-67	29.9	
I43-6	90°	-67	25.9	
Avg.			28.4	
I43-4	90°	72	32.0	
I43-5	90°	72	33.0	
I43-6	90°	72	28.5	
Avg.			31.2	
I43-4	90°	350	42.6	
I43-5	90°	350	40.4	
I43-6	90°	350	40.6	
Avg.			41.1	
I43-4	90°	450	43.6	
I43-5	90°	450	42.1	
I43-6	90°	450	42.3	
Avg.			42.7	

Test: Coefficient of Thermal Expansion				
Materials: HyE 1076J				
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
1	0°	-67	0.152	
2	0°	-67	0.120	
3	0°	-67	0.180	
Avg.			0.151	
1	0°	72	-0.560	
2	0°	72	-0.578	
3	0°	72	-0.475	
Avg.			-0.538	
1	0°	260	-0.365	
2	0°	260	-0.486	
3	0°	260	-0.457	
Avg.			-0.436	
1	0°	350	-0.288	
2	0°	350	-0.492	
3	0°	350	-0.180	
Avg.			-0.320	
1	90°	-67	21.9	
2	90°	-67	22.4	
3	90°	-67	22.2	
Avg.			22.2	
4	90°	72	23.8	
5	90°	72	25.2	
6	90°	72	24.3	
Avg.			24.4	

Test: Coefficient of Thermal Expansion				
Materials: HyE 1076J				
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
4	90°	260	31.2	
5	90°	260	31.4	
6	90°	260	31.6	
Avg.			31.4	
4	90°	350	34.7	
5	90°	350	35.0	
6	90°	350	34.2	
Avg.			34.6	
1	±45°	-67	3.02	
2	±45°	-67	3.39	
3	±45°	-67	2.85	
Avg.			3.08	
1	±45°	72	2.98	
2	±45°	72	2.44	
3	±45°	72	2.32	
Avg.			2.58	
1	±45°	260	2.41	
2	±45°	260	2.58	
3	±45°	260	2.61	
Avg.			2.53	
1	±45°	350	2.42	
2	±45°	350	2.81	
3	±45°	350	2.78	
Avg.			2.67	

Test: Coefficient of Thermal Expansion

Materials: G-160/6535-1

Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6}in/in-°F)	Remarks
K20-A	0°	-67	0.17	
K20-B	0°	-67	-0.06	
K20-C	0°	-67	0.15	
Avg.			0.08	
K20-A	0°	72	-0.34	
K20-B	0°	72	-0.41	
K20-C	0°	72	-0.38	
Avg.			-0.37	
K20-A	0°	260	-0.27	
K20-B	0°	260	-0.39	
K20-C	0°	260	-0.48	
Avg.			-0.38	
K20-A	0°	350	-0.15	
K20-B	0°	350	-0.17	
K20-C	0°	350	-0.29	
Avg.			-0.20	
K20-D	90°	-67	23.0	
K20-E	90°	-67	22.0	
K20-F	90°	-67	22.5	
Avg.			22.5	
K20-D	90°	72	24.5	
K20-E	90°	72	24.0	
K20-F	90°	72	25.3	
Avg.			24.8	

Test: Coefficient of Thermal Expansion				
Materials: G-160/6535-1				
Specimen Number	Fiber Orientation	Temp. Range (°F)	Coeff. Therm. Expansion (10^{-6} in/in-°F)	Remarks
K20-D	90°	260	29.8	
K20-E	90°	260	30.2	
K20-F	90°	260	29.9	
Avg.			30.0	
K20-D	90°	350	33.2	
K20-E	90°	350	31.7	
K20-F	90°	350	32.3	
Avg.			32.4	
K40-A	±45	-67	3.05	
K40-B	±45	-67	2.60	
K40-C	±45	-67	3.13	
Avg.			2.93	
K40-A	±45	72	2.25	
K40-B	±45	72	2.51	
K40-C	±45	72	2.61	
Avg.			2.46	
K40-A	±45	260	2.24	
K40-B	±45	250	2.23	
K40-C	±45	260	2.24	
Avg.			2.24	
K40-A	±45	350	2.88	
K40-B	±45	350	2.55	
K40-C	±45	350	2.19	
Avg.			2.54	

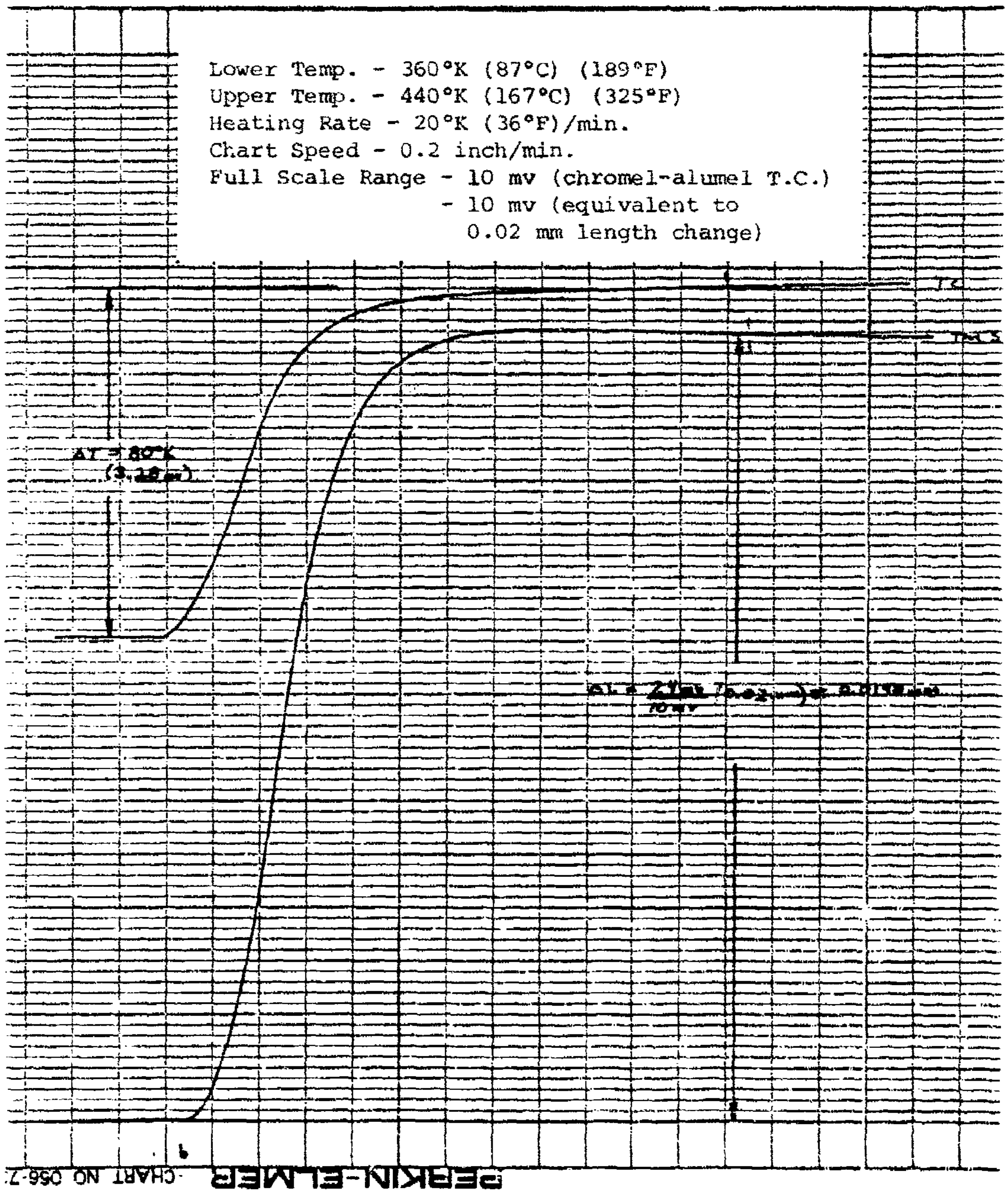

Figure K-1. Thermal Expansion Characteristics of SiC/5506 Composite Laminate; 90° Fiber Direction.

APPENDIX L
SPECIFIC HEAT DATA

All of the specific heat data generated during this program are presented in this section. A typical set of differential scanning calorimeter (DSC) traces, from which specific heat is determined, is included at the end of this section.

The values listed in the succeeding tables were computed according to the following equation:

$$C_p(\text{sample}) = \frac{\text{mass of sapphire stnd.}}{\text{mass of sample}} \times \frac{D_3-D_1}{D_2-D_1} \times C_p(\text{sapphire stnd.}),$$

where, D_1, D_2 and D_3 represent the relative displacements of the DSC curves for the empty aluminum pan, sapphire reference, and sample, respectively. For the sample traces included,

$$C_p(\text{HyE 1076J,\#1}) = \frac{8.54\text{gm}}{4.23\text{gm}} \times \frac{12.4\text{ div} - 17.2\text{ div}}{10.8\text{ div} - 17.2\text{ div}} \times 0.22545\ \frac{\text{cal}}{\text{gm-°K}}$$

$$= 0.341\text{ cal/gm-°K, or } 0.341\text{ BTU/lb-°F at } 400\text{°K, or } 260\text{°F.}$$

Test: Specific Heat

Materials: See Remarks Column

Specimen Number	Avg. Temp. (°F)	Specific Heat (Btu/lb-°F)	Remarks	
---	-67	0.081	T300/AFR800	These are average values.
---	72	0.203	T300/AFR800	Individual values were
---	260	0.302	T300/AFR800	detroyed in flood.
---	350	0.308	T300/AFR800	
---	-67	0.186	SiC/5506	These are average values.
---	72	0.221	SiC/5506	Individual values were
---	260	0.279	SiC/5506	destroyed in flood.
---	350	0.309	SiC/5506	
1	-67	0.110	HyE 2034D	
1	72	0.202	HyE 2034D	
1	260	0.642	HyE 2034D	
1	350	0.718	HyE 2034D	
1	-67	0.123	T300/V378A	
1	72	0.206	T300/V378A	
1	260	0.748	T300/V378A	
1	350	0.761	T300/V378A	

Test: Specific Heat			
Materials: HyE 1076J			
Specimen Number	Avg. Temp. (°F)	Specific Heat (Btu/lb-°F)	Remarks
1	-67	0.213	
2	-67	0.124	
3	-67	0.123	
Avg.		0.153	
1	72	0.267	
2	72	0.177	
3	72	0.172	
Avg.		0.205	
1	260	0.341	
2	260	0.253	
3	260	0.228	
Avg.		0.274	
1	350	0.411	
2	350	0.302	
3	350	0.278	
Avg.		0.330	

Test: Specific Heat			
Materials: G-160/6535-1			
Specimen Number	Avg. Temp. (°F)	Specific Heat (Btu/lb-°F)	Remarks
1	-67	0.115	
2	-67	0.180	
3	-67	0.167	
Avg.		0.154	
1	72	0.164	
2	72	0.240	
3	72	0.201	
Avg.		0.202	
1	260	0.230	
2	260	0.322	
3	260	0.292	
Avg.		0.281	
1	350	0.264	
2	350	0.381	
3	350	0.355	
Avg.		0.333	

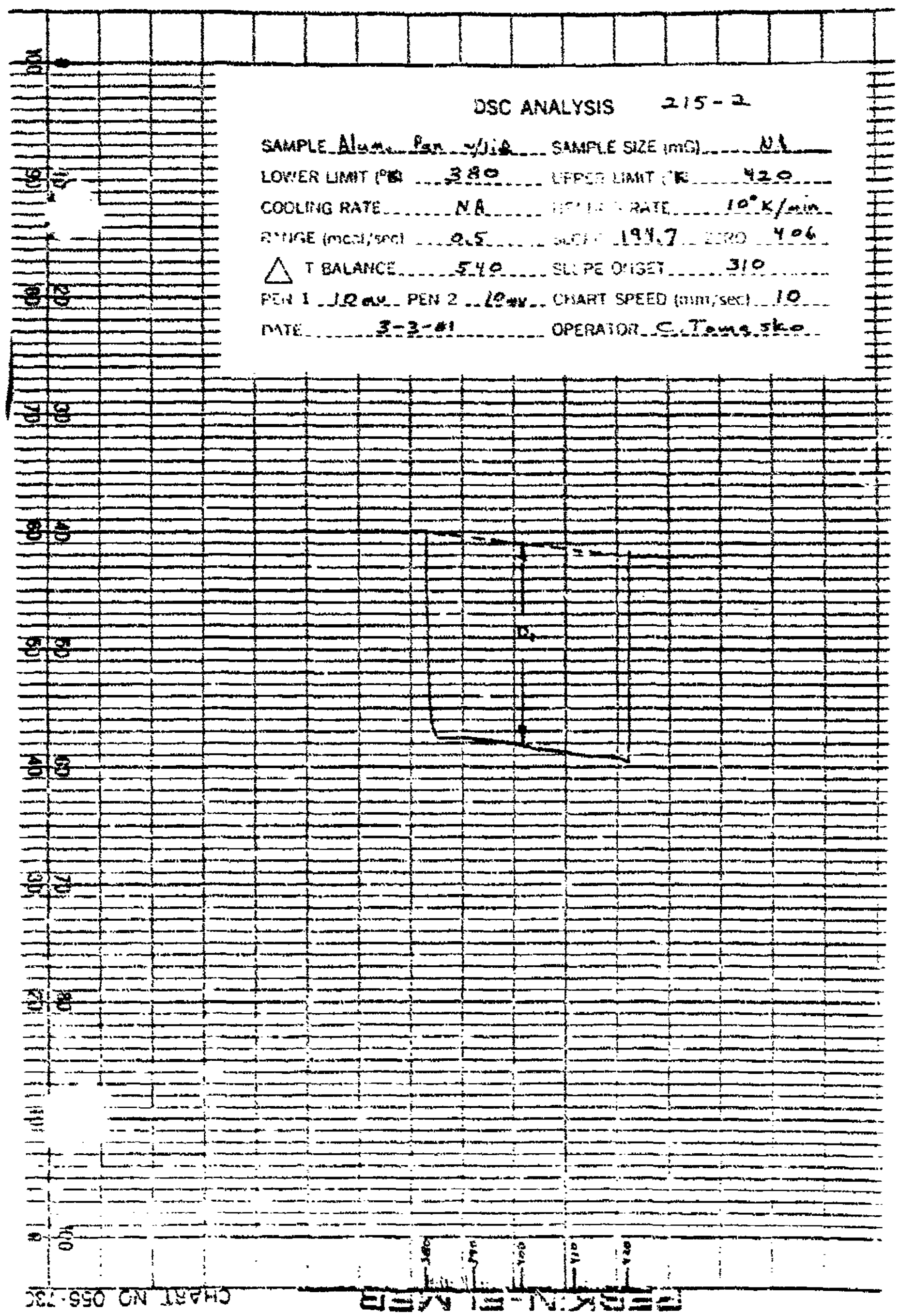

Figure L-1. DSC Analysis of Empty Sample Pan.

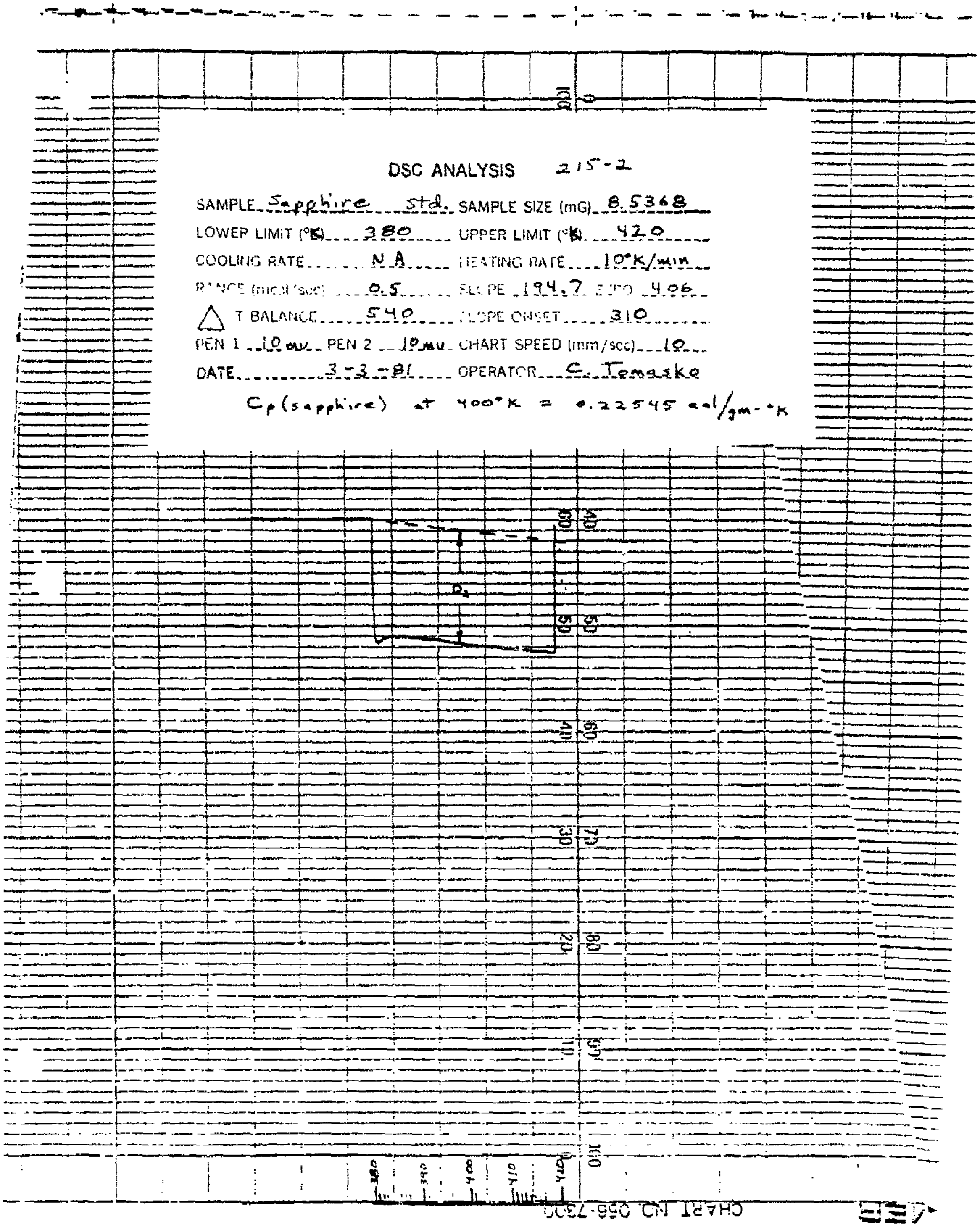

Figure L-2. DSC Analysis of Sapphire Reference Standard.

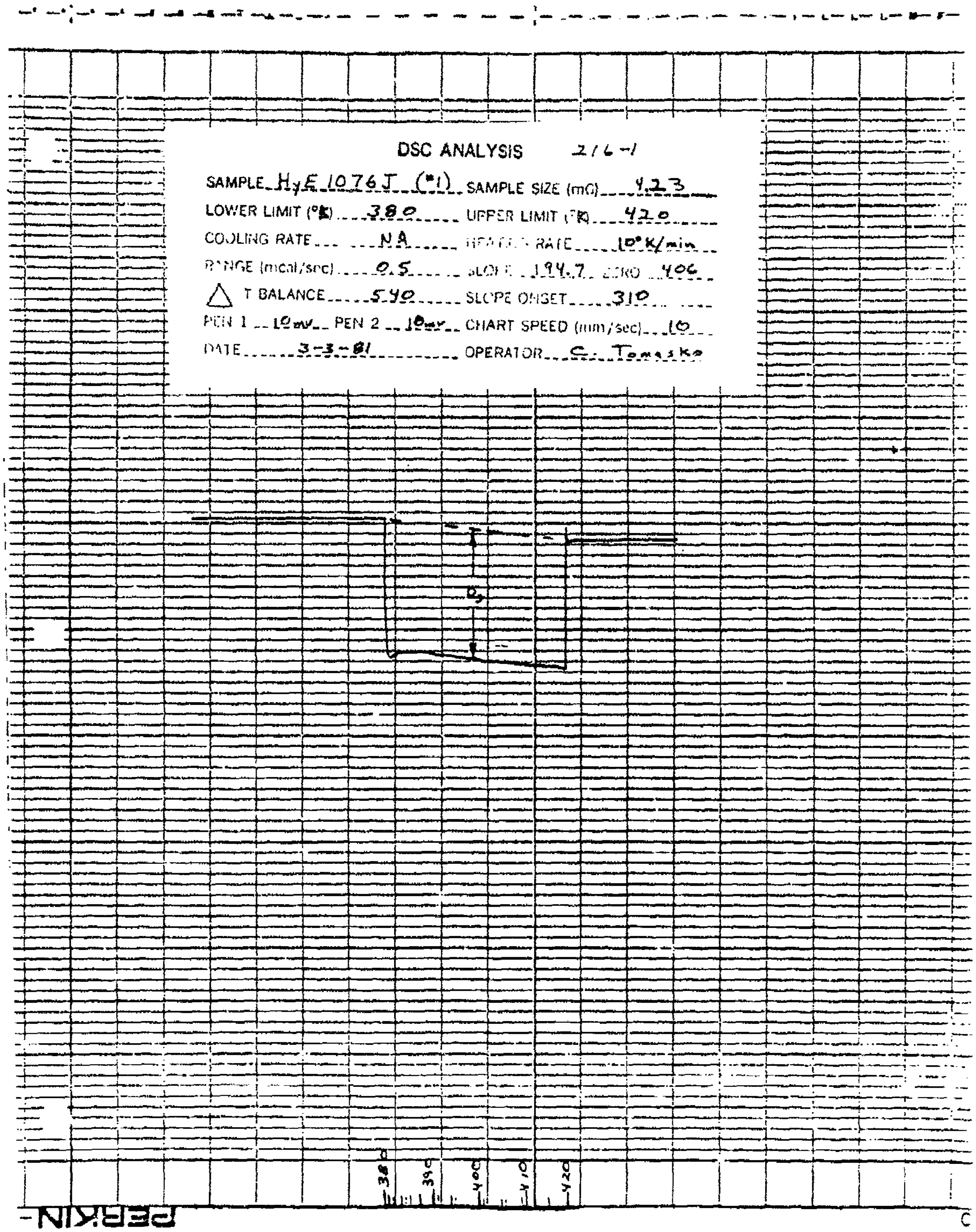

Figure L-3. DSC Analysis of HyE 1076J Graphite/Epoxy Composite Material.

APPENDIX M
THERMAL CONDUCTIVITY DATA

All of the thermal conductivity measurements made during this program are tabulated in this section. The average values presented in Sections 4.1 through 4.6 were taken from linear regression curves drawn through all of the respective data points tabulated here.

Test: Thermal Conductivity				
Materials: T300/AFR800				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
F37-1	0°	-69	0.295	
F37-1	0°	-30	0.341	
F37-1	0°	56	0.364	
F37-1	0°	60	0.486	
F37-1	0°	65	0.854	
F37-1	0°	67	0.244	
F37-1	0°	70	0.611	
F37-1	0°	74	0.308	
F37-1	0°	77	0.399	
F37-1	0°	81	0.499	
F37-1	0°	82	0.301	
F37-1	0°	85	0.568	
F37-1	0°	91	0.552	
F37-1	0°	93	0.295	
F37-1	0°	96	0.434	
F37-1	0°	100	0.331	
F37-1	0°	101	0.491	
F37-1	0°	106	0.508	
F37-1	0°	112	0.487	
F37-1	0°	117	0.494	
F37-1	0°	118	0.529	
F37-1	0°	125	0.459	
F37-1	0°	130	0.524	
F37-1	0°	136	0.508	
F37-1	0°	136	0.385	
F37-1	0°	145	0.529	
F37-1	0°	150	0.481	
F37-1	0°	160	0.544	
F37-1	0°	164	0.557	
F37-1	0°	222	0.410	

Test: Thermal Conductivity				
Materials: T300/AFR800				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
F37-1	0°	235	0.558	
F37-1	0°	291	0.463	
F37-1	0°	325	0.467	
F37-1	0°	350	0.510	
F37-2	0°	-83	0.379	
F37-2	0°	-59	0.375	
F37-2	0°	89	0.564	
F37-2	0°	117	0.486	
F37-2	0°	144	0.536	
F37-2	0°	170	0.502	
F37-2	0°	217	0.551	
F37-2	0°	279	0.515	
F37-2	0°	354	0.643	
F37-3	0°	-75	0.294	
F37-3	0°	-50	0.299	
F37-3	0°	-22	0.306	
F37-3	0°	91	0.494	
F37-3	0°	119	0.383	
F37-3	0°	146	0.424	
F37-3	0°	173	0.431	
F37-3	0°	222	0.443	
F37-3	0°	273	0.479	
F37-3	0°	334	0.503	
F37-3	0°	351	0.500	

Test: Thermal Conductivity				
Materials: T300/AFR800				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
F38-1	±45°	-61	0.343	
F38-1	±45°	-50	0.373	
F38-1	±45°	61	0.288	
F38-1	±45°	100	0.360	
F38-1	±45°	139	0.311	
F38-1	±45°	217	0.418	
F38-1	±45°	300	0.429	
F38-1	±45°	343	0.430	
F38-2	±45°	-82	0.280	
F38-2	±45°	-49	0.297	
F38-2	±45°	90	0.374	
F38-2	±45°	116	0.370	
F38-2	±45°	142	0.370	
F38-2	±45°	173	0.364	
F38-2	±45°	221	0.396	
F38-2	±45°	269	0.414	
F38-2	±45°	323	0.447	

Test: Thermal Conductivity				
Materials: SiC/5506				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
G10-1	0°	-102	0.456	
G10-1	0°	- 48	0.567	
G10-1	0°	88	0.512	
G10-1	0°	106	0.650	
G10-1	0°	128	0.583	
G10-1	0°	156	0.623	
G10-1	0°	182	0.602	
G10-1	0°	238	0.581	
G10-1	0°	290	0.626	
G10-1	0°	339	0.608	
G10-1	0°	351	0.672	
G10-1	0°	395	0.547	
G10-2	0°	- 45	0.573	
G10-2	0°	- 16	0.521	
G10-2	0°	88	0.579	
G10-2	0°	113	0.576	
G10-2	0°	143	0.665	
G10-2	0°	169	0.613	
G10-2	0°	198	0.630	
G10-2	0°	241	0.636	
G10-2	0°	293	0.645	
G10-2	0°	338	0.662	
G10-2	0°	376	0.630	

Test: Thermal Conductivity				
Materials: HyE 2034D				
Specimen Number	Fiber Orientation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
H32-1	0°	-61	0.410	
H32-1	0°	-28	0.476	
H32-1	0°	4	0.511	
H32-1	0°	81	0.731	
H32-1	0°	111	0.881	
H32-1	0°	139	0.588	
H32-1	0°	177	0.856	
H32-1	0°	220	0.859	
H32-1	0°	268	1.019	
H32-1	0°	313	1.031	
H32-1	0°	358	1.039	
H32-2	0°	-76	0.489	
H32-2	0°	-44	0.540	
H32-2	0°	1	0.489	
H32-2	0°	79	0.648	
H32-2	0°	104	0.926	
H32-2	0°	135	0.908	
H32-2	0°	166	0.787	
H32-2	0°	212	0.874	
H32-2	0°	262	0.937	
H32-2	0°	306	0.943	
H32-2	0°	352	0.972	

Test: Thermal Conductivity				
Materials: HyE 2034D				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
H32-3	0°	-57	0.643	
H32-3	0°	-35	0.633	
H32-3	0°	8	0.701	
H32-3	0°	81	0.771	
H32-3	0°	111	0.949	
H32-3	0°	136	0.758	
H32-3	0°	174	0.720	
H32-3	0°	217	0.735	
H32-3	0°	264	0.788	
H32-3	0°	312	0.841	
H32-3	0°	353	0.863	

Test: Thermal Conductivity				
Materials: HyE 2034D				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
H37-1	±45°	99	0.516	
H37-1	±45°	113	0.625	
H37-1	±45°	111	0.507	
H37-1	±45°	146	0.551	
H37-1	±45°	140	0.523	
H37-1	±45°	170	0.607	
H37-1	±45°	170	0.629	
H37-1	±45°	199	0.563	
H37-1	±45°	235	0.594	
H37-1	±45°	231	0.585	
H37-1	±45°	286	0.596	
H37-1	±45°	331	0.584	
H37-1	±45°	339	0.603	
H37-2	±45°	96	0.460	
H37-2	±45°	110	0.601	
H37-2	±45°	138	0.572	
H37-2	±45°	164	0.533	
H37-2	±45°	192	0.576	
H37-2	±45°	228	0.555	
H37-2	±45°	274	0.603	
H37-2	±45°	305	0.638	
H37-2	±45°	366	0.555	
H37-3	±45°	80	0.703	
H37-3	±45°	88	1.417	
H37-3	±45°	91	0.985	
H37-3	±45°	101	1.464	
H37-3	±45°	111	1.44	
H37-3	±45°	125	1.238	
H37-3	±45°	196	0.764	
H37-3	±45°	244	0.613	

Test: Thermal Conductivity				
Materials: HyE 2034D				
Specimen Number	Fiber Orientation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
H37-3	±45°	286	0.377	
H37-3	±45°	326	0.330	
H37-3	±45°	370	0.375	
H37-3	±45°	55	0.257	
H37-3	±45°	40	0.390	
H37-3	±45°	-130	1.093	

Test: Thermal Conductivity				
Materials: T300/V378A				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
I43-1	0°	62	0.331	
I43-1	0°	92	0.363	
I43-1	0°	121	0.372	
I43-1	0°	154	0.384	
I43-1	0°	188	0.397	
I43-1	0°	230	0.410	
I43-1	0°	272	0.440	
I43-1	0°	310	0.452	
I43-1	0°	337	0.457	
I43-2	0°	61	0.305	
I43-2	0°	92	0.335	
I43-2	0°	123	0.346	
I43-2	0°	157	0.331	
I43-2	0°	235	0.396	
I43-2	0°	235	0.398	
I43-2	0°	276	0.399	
I43-2	0°	316	0.408	
I43-2	0°	339	0.419	
I43-3	0°	-51	0.282	
I43-3	0°	-20	0.116	
I43-3	0°	-18	0.244	
I43-3	0°	61	0.370	
I43-3	0°	92	0.365	
I43-3	0°	120	0.395	
I43-3	0°	154	0.399	
I43-3	0°	191	0.356	
I43-3	0°	230	0.424	
I43-3	0°	273	0.467	
I43-3	0°	312	0.436	
I43-3	0°	339	0.462	

Test: Thermal Conductivity				
Materials: T300/V378A				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity ($Btu-ft/ft^2-hr-°F$)	Remarks
I44-1	±45°	-64	0.249	
I44-1	±45°	-39	0.242	
I44-1	±45°	-19	0.249	
I44-1	±45°	72	0.225	
I44-1	±45°	97	0.327	
I44-1	±45°	124	0.328	
I44-1	±45°	121	0.318	
I44-1	±45°	123	0.320	
I44-1	±45°	149	0.329	
I44-1	±45°	195	0.335	
I44-1	±45°	207	0.352	
I44-1	±45°	255	0.354	
I44-1	±45°	280	0.363	
I44-1	±45°	369	0.394	
I44-1	±45°	367	0.287	
I44-1	±45°	412	0.405	
I44-1	±45°	436	0.414	
I44-2	±45°	-82	0.273	
I44-2	±45°	-44	0.351	
I44-2	±45°	18	0.388	
I44-2	±45°	119	0.329	
I44-2	±45°	175	0.347	
I44-2	±45°	255	0.376	
I44-2	±45°	368	0.432	
I44-2	±45°	368	0.426	
I44-2	±45°	435	0.462	

Test: Thermal Conductivity				
Materials: T300/V378A				
Specimen Number	Fiber Orientation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
I44-3	±45°	-66	0.264	
I44-3	±45°	-63	0.271	
I44-3	±45°	-55	0.269	
I44-3	±45°	93	0.290	
I44-3	±45°	121	0.288	
I44-3	±45°	177	0.287	
I44-3	±45°	260	0.343	
I44-3	±45°	374	0.367	
I44-3	±45°	418	0.376	
I44-3	±45°	447	0.383	

Test: Thermal Conductivity				
Materials: HyE 1076J				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
J33-1	±45°	92	0.445	
J33-1	±45°	124	0.507	
J33-1	±45°	145	0.545	
J33-1	±45°	214	0.578	
J33-1	±45°	258	0.570	
J33-1	±45°	311	0.578	
J33-1	±45°	341	0.601	
J33-2	±45°	91	0.297	
J33-2	±45°	116	0.429	
J33-2	±45°	138	0.400	
J33-2	±45°	203	0.417	
J33-2	±45°	248	0.471	
J33-2	±45°	305	0.513	
J33-2	±45°	334	0.453	
J33-3	±45°	93	0.497	
J33-3	±45°	120	0.493	
J33-3	±45°	145	0.460	
J33-3	±45°	208	0.604	
J33-3	±45°	260	0.563	
J33-3	±45°	305	0.572	
J33-3	±45°	343	0.580	
J33-3	±45°	-72	0.226	
J33-3	±45°	-60	0.222	
J33-3	±45°	-51	0.272	
J33-3	±45°	-25	0.273	

Test: Thermal Conductivity				
Materials: HyE 1076J				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft²-hr-°F)	Remarks
J34-1	0°	-75	0.418	
J34-1	0°	-47	0.397	
J34-1	0°	-26	0.397	
J34-1	0°	91	0.380	
J34-1	0°	111	0.416	
J34-1	0°	141	0.402	
J34-1	0°	211	0.432	
J34-1	0°	278	0.494	
J34-1	0°	324	0.480	
J34-1	0°	335	0.519	
J34-2	0°	95	0.393	
J34-2	0°	109	0.443	
J34-2	0°	139	0.451	
J34-2	0°	187	0.453	
J34-2	0°	234	0.460	
J34-2	0°	263	0.460	
J34-2	0°	308	0.509	
J34-2	0°	333	0.531	
J34-2	0°	343	0.535	
J34-3	0°	91	0.425	
J34-3	0°	128	0.437	
J34-3	0°	138	0.447	
J34-3	0°	205	0.483	
J34-3	0°	269	0.488	
J34-3	0°	312	0.518	
J34-3	0°	327	0.521	

Test: Thermal Conductivity				
Materials: G-160/6535-1				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
K20-1	0°	81	0.397	
K20-1	0°	107	0.421	
K20-1	0°	132	0.458	
K20-1	0°	160	0.466	
K20-1	0°	217	0.509	
K20-1	0°	265	0.517	
K20-1	0°	311	0.509	
K20-1	0°	352	0.531	
K20-2	0°	80	0.437	
K20-2	0°	106	0.450	
K20-2	0°	133	0.456	
K20-2	0°	163	0.496	
K20-2	0°	212	0.511	
K20-2	0°	255	0.580	
K20-2	0°	303	0.743	
K20-2	0°	342	0.619	
K20-3	0°	-25	0.113	
K20-3	0°	-25	0.253	
K20-3	0°	-19	0.208	
K20-3	0°	-3	0.258	
K20-3	0°	85	0.357	
K20-3	0°	111	0.388	
K20-3	0°	133	0.453	
K20-3	0°	164	0.479	
K20-3	0°	217	0.641	
K20-3	0°	267	0.597	
K20-3	0°	312	0.658	
K20-3	0°	347	0.665	

Test: Thermal Conductivity				
Materials: G-160/6535-1				
Specimen Number	Fiber Orien-tation	Temp. (°F)	Thermal Conductivity (Btu-ft/ft^2-hr-°F)	Remarks
K40-1	±45°	-62	0.395	
K40-1	±45°	-47	0.390	
K40-1	±45°	-21	0.426	
K40-1	±45°	107	0.435	
K40-1	±45°	131	0.457	
K40-1	±45°	161	0.509	
K40-1	±45°	256	0.496	
K40-1	±45°	300	0.659	
K40-1	±45°	345	0.594	
K40-2	±45°	80	0.395	
K40-2	±45°	105	0.449	
K40-2	±45°	133	0.437	
K40-2	±45°	162	0.459	
K40-2	±45°	208	0.468	
K40-2	±45°	252	0.497	
K40-2	±45°	297	0.546	
K40-2	±45°	344	0.516	
K40-3	±45°	81	0.417	
K40-3	±45°	109	0.438	
K40-3	±45°	131	0.447	
K40-3	±45°	174	0.473	
K40-3	±45°	219	0.448	
K40-3	±45°	265	0.454	
K40-3	±45°	311	0.513	
K40-3	±45°	350	0.521	

APPENDIX N

GLASS-TRANSITION TEMPERATURE DATA

The glass-transition temperatures determined for the materials characterized during this program are presented here along with a typical loss-modulus vs. temperature trace, from which the T_g's are determined by DMA.

GLASS TRANSITION TEMPERATURE

Material	Dry T_g (°F)	Wet[1] T_g (°F)
T300/AFR800	468	381
SiC/5506	394	293
HyE 2034D	430	342
T300/V378A[2]	702	702
HyE 1076J	518	493
G-160/6535-1	507	471

[1]Specimen exposed to 160°F (71°C) and 100% R.H. until it reached equilibrium weight gain.

[2]This material gained weight very rapidly during humidity aging. If it dried just as rapidly also, the specimen may have been completely dry by the end of the test, hence, the wet value indicated may actually have been for a dry material.

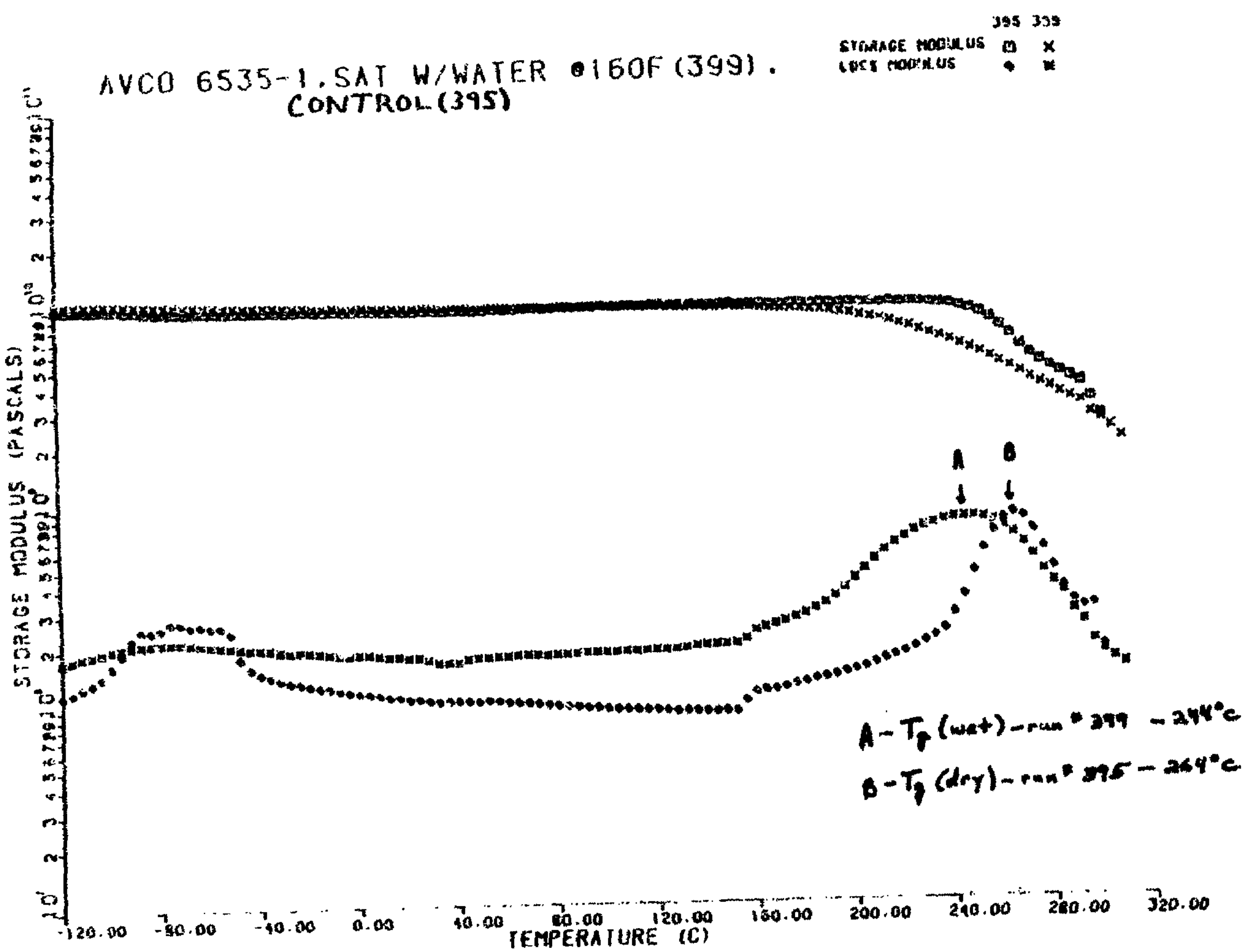

Figure N-1. Dynamic Mechanical Analysis of G-160/6535-1 Graphite/Epoxy Composite Material.

APPENDIX O
HUMIDITY AGED TENSION DATA

All of the tensile data generated during this program on specimens which had been humidity aged at 160°F (71°C) and 100% R.H. are presented in this section. Summaries of these data are tabulated and plotted in the form of stress-strain curves in Sections 4.1 through 4.6.

Test: Tension After Environmental Aging @ 160°F & 100% R.H. Material: T300/AFR800

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (μin/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
F15-2	90°	72	6.37	1.45	1.55	---	4580	196	0.63	50% saturation
F15-8	90°	72	4.22	1.46	1.49	---	3080	196	0.63	50% saturation
F15-10	90°	72	5.60	1.5[illegible]	1.08	---	4000	196	0.63	50% saturation
F16-5	90°	72	5.60	1.54	0.95	---	3950	196	0.60	50% saturation
F16-10	90°	72	4.85	1.42	3.54	---	3500	196	0.62	50% saturation
Avg.			5.33	1.48	1.72	---	3820		0.62	
Std.Dev.			0.82	0.06	1.05	---	570		0.01	
F14-3	90°	260	2.95	1.62	0.53	---	2680	196	0.40	50% saturation
F15-1	90°	260	2.70	1.40	0.47	---	2600	196	0.62	50% saturation
F15-9	90°	260	3.52	1.50	0.47	---	3380	196	0.63	50% saturation
F16-9	90°	260	3.88	1.54	0.44	---	3750	196	0.61	50% saturation
F17-8	90°	260	3.53	1.70	0.48	---	3180	196	0.65	50% saturation
Avg.			3.31	1.55	0.48	---	3120		0.58	
Std.Dev.			0.48	0.11	0.03	---	480		0.10	
F15-4	90°	72	3.62	1.41	3.62	---	3030	1,416	1.36	100% saturation
F16-7	90°	72	4.03	1.42	4.03	---	2840	1,416	1.26	100% saturation
F17-9	90°	72	3.60	1.41	3.60	---	2560	1,416	1.27	100% saturation
F18-3	90°	72	2.85	1.55	2.84	---	1840	1,416	1.24	100% saturation
Avg.			3.52	1.45	3.52	---	2570		1.28	
Std.Dev.			0.49	0.07	0.49	---	520		0.04	
F14-10	90°	260	1.78	0.91	1.42	---	2190	1,848	1.30	100% saturation
F16-3	90°	260	1.28	1.10	0.95	---	1290	1,848	1.26	100% saturation
F17-3	90°	260	1.47	1.07	1.47	---	1450	1,848	1.27	100% saturation
F18-8	90°	260	1.42	1.01	1.19	---	1440	1,848	1.30	100% saturation
Avg.			1.49	1.02	1.26	---	1590		1.27	
Std.Dev.			0.21	0.08	0.24	---	400		0.04	

Test: Tension After Environmental Aging @ 160°F & 100% R.H. Material: SiC/5506

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (μin/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
G9-2	90°	72	9.04	2.97	2.69	---	3600	175	0.60	50% saturation
G9-11	90°	72	8.20	3.06	2.25	---	3300	175	0.62	50% saturation
G22-8	90°	72	9.50	2.83	2.42	---	3870	175	0.59	50% saturation
G25-8	90°	72	8.66	3.44	1.65	---	3190	175	0.59	50% saturation
G26-8	90°	72	8.43	3.08	2.29	---	3200	175	0.56	50% saturation
Avg.			8.77	3.08	2.26	---	3420		0.59	
Std.Dev			0.51	0.23	0.38	---	310		0.02	
G9-10	90°	260	4.27	0.92	1.14	---	8300	175	0.61	50% saturation
G22-4	90°	260	3.98	1.09	0.82	---	8500	175	0.62	50% saturation
G24-6	90°	260	3.78	1.15	0.66	---	7700	175	0.62	50% saturation
G25-2	90°	260	3.77	1.34	0.88	---	6700	175	0.58	50% saturation
G26-6	90°	260	3.29	1.03	0.56	---	7000	175	0.58	50% saturation
Avg.			3.82	1.11	0.81	---	7640		0.60	
Std.Dev			0.36	0.16	0.22	---	790		0.02	
G9-8	90°	72	5.02	2.37	3.10	---	2380	1,546	1.28	100% saturation
G24-5	90°	72	6.52	2.49	3.10	---	3000	1,546	1.29	100% saturation
G25-7	90°	72	6.81	2.64	2.29	---	2900	1,546	1.23	100% saturation
G26-3	90°	72	6.39	2.52	3.12	---	2910	1,546	1.24	100% saturation
G26-9	90°	72	6.14	2.87	1.30	---	2630	1,546	1.27	100% saturation
Avg.			6.17	2.58	2.58	---	2760		1.26	
Std.Dev			0.69	0.19	0.90	---	260		0.03	
G9-1	90°	260	2.02	1.08	0.81	---	3680	1,546	1.27	100% saturation
G22-6	90°	260	1.75	0.51	0.64	---	4880	1,546	1.21	100% saturation
G22-7	90°	260	1.89	0.70	0.66	---	4310	1,546	1.23	100% saturation
G24-8	90°	260	1.82	0.47	0.55	---	6100	1,546	1.29	100% saturation
G25-1	90°	260	2.19	1.01	0.72	---	6070	1,546	1.32	100% saturation
Avg.			1.93	0.75	0.68	---	5010		1.26	
Std.Dev			0.17	0.28	0.10	---	1070		0.04	

Test: Tension After Environmental Aging @ 160°F & 100% R.H. Material: HyE 2034D

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (μin/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
H36-8	90°	72	2.67	0.96	0.76	---	2830	216.75	0.79	50% saturation
H36-7	90°	72	2.13	0.90	0.75	---	2400	216.75	0.79	50% saturation
H36-1	90°	72	2.21	0.96	1.15	---	2400	216.75	0.80	50% saturation
H36-4	90°	72	2.85	0.97	1.08	---	3000	216.75	0.79	50% saturation
H36-2	90°	72	2.79	0.96	1.14	---	2960	216.75	0.78	50% saturation
Avg.			2.53	0.95	0.98	---	2720		0.79	
Std.Dev.			0.34	0.03	0.20	---	300		0.01	
H35-2	90°	260	1.89	0.74	0.82	---	2830	216.75	0.77	50% saturation
H35-4	90°	260	1.81	0.67	1.04	---	2920	216.75	0.79	50% saturation
H35-5	90°	260	1.44	0.76	0.62	---	2180	216.75	0.78	50% saturation
H35-6	90°	260	1.69	0.69	0.80	---	2670	216.75	0.80	50% saturation
H36-10	90°	260	1.76	0.71	0.72	---	2690	216.75	0.80	50% saturation
Avg.			1.72	0.71	0.80	---	2660		0.79	
Std.Dev.			0.17	0.04	0.16	---	280		0.01	
H3-8	90°	72	1.65	1.00	1.22	---	1700	982	1.17	100% saturation
H4-1	90°	72	2.25	1.07	1.14	---	2200	982	1.14	100% saturation
H4-6	90°	72	2.38	1.03	1.71	---	2300	982	1.22	100% saturation
H4-7	90°	72	1.87	0.99	1.60	---	2000	982	1.17	100% saturation
H6-5	90°	72	2.09	0.93	1.77	---	2300	982	1.19	100% saturation
Avg.			2.05	1.00	1.49	---	2100	982	1.18	
Std.Dev.			0.29	0.05	0.29	---	260		0.03	
H3-4	90°	260	0.88	0.43	0.88	---	2100	982	1.17	100% saturation
H3-5	90°	260	0.94	0.47	0.94	---	2100	982	1.16	100% saturation
H6-4	90°	260	1.21	0.48	1.01	---	2700	982	1.17	100% saturation
H6-8	90°	260	1.04	0.63	0.82	---	2000	982	1.17	100% saturation
H7-4	90°	260	1.13	0.59	0.80	---	2100	982	1.28	100% saturation
Avg.			1.04	0.52	0.89	---	2200		1.19	
Std.Dev.			0.13	0.09	0.09	---	280		0.05	

Test: Tension After Environmental Aging @ 160°F & 100% R.H. Material: T300/V378A

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (μin/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
I15-2	90°	72	5.48	1.31	4.08	---	4100	18	0.75	50% saturation
I18-1	90°	72	6.11	1.39	2.22	---	4600	18	0.74	50% saturation
I19-3	90°	72	6.60	1.32	4.25	---	6200	18	0.79	50% saturation
I20-6	90°	72	4.97	1.28	4.97	---	3800	18	0.81	50% saturation
I21-5	90°	72	4.66	1.27	4.66	---	3600	18	0.80	50% saturation
Avg.			5.56	1.31	4.03	---	4460		0.78	
Std.Dev.			0.80	0.05	1.07	---	1040		0.03	
I15-1	90°	350	3.92	1.16	0.85	---	3800	18	0.72	50% saturation
I18-3	90°	350	4.48	1.17	0.63	---	4700	18	0.79	50% saturation
I19-2	90°	350	4.81	0.96	1.67	---	3900	18	0.83	50% saturation
I20-3	90°	350	3.54	1.08	0.79	---	3700	18	0.78	50% saturation
I21-6	90°	350	2.62	1.07	0.75	---	2700	18	0.81	50% saturation
Avg.			3.87	1.09	0.94	---	3760		0.79	
Std.Dev.			0.86	0.08	0.42	---	710		0.04	
I15-4	90°	72	3.96	1.34	3.54	---	3000	2588	1.76	100% saturation
I15-6	90°	72	3.58	1.30	3.55	---	2700	2588	1.75	100% saturation
I15-7	90°	72	3.81	1.28	3.43	---	2930	2588	1.77	100% saturation
I18-4	90°	72	4.22	1.32	3.45	---	3250	2588	1.76	100% saturation
I18-9	90°	72	3.96	1.30	3.94	---	2970	2588	1.77	100% saturation
Avg.			3.90	1.31	3.58	---	2970		1.76	
Std.Dev.			0.24	0.02	0.21	---	200		0.01	
I18-6	90°	350	0.84	0.94	0.66	---	900	2588	1.77	100% saturation
I19-7	90°	350	0.59	0.78	0.29	---	700	2588	1.75	100% saturation
I20-10	90°	350	0.86	1.10	0.59	---	800	2588	1.64	100% saturation
I21-2	90°	350	0.86	1.15	0.36	---	1000	2588	1.73	100% saturation
I21-3	90°	350	0.78	0.71	0.70	---	800	2588	1.74	100% saturation
Avg.			0.79	0.94	0.52	---	840		1.73	
Std.Dev.			0.11	0.19	0.19	---	110		0.05	

Test: Tension After Environmental Aging @ 160°F & 100% R.H. Material: HyE 1076J

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (μin/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
J27-6	90°	72	5.98	1.45	2.43	---	4300	162	0.80	50% saturation
J28-10	90°	72	4.94	1.37	4.94	---	3600	162	0.78	50% saturation
J29-6	90°	72	4.30	1.42	4.30	---	3000	162	0.77	50% saturation
J30-4	90°	72	4.64	1.29	4.64	---	3600	162	0.71	50% saturation
J30-9	90°	72	4.14	1.52	1.15	---	3000	162	0.81	50% saturation
Avg.			4.80	1.41	3.49	---	3500		0.77	
Std.Dev			0.73	0.09	1.63	---	540		0.04	
J26-9	90°	260	3.63	1.24	2.06	---	3200	162	0.75	50% saturation
J27-4	90°	260	2.47	1.22	0.72	---	2400	162	0.76	50% saturation
J27-7	90°	260	3.13	1.17	0.89	---	3000	162	0.80	50% saturation
J28-6	90°	260	2.58	1.07	1.95	---	2500	162	0.75	50% saturation
J29-9	90°	260	2.74	1.31	0.93	---	2400	162	0.73	50% saturation
Avg.			2.91	1.20	1.31	---	2700		0.76	
Std.Dev			0.47	0.09	0.64	---	370		0.03	
J26-4	90°	72	4.26	1.49	4.26	---	2800	1,774	1.18	100% saturation
J26-10	90°	72	4.15	1.52	4.15	---	2700	1,774	1.14	100% saturation
J27-5	90°	72	3.80	1.42	2.80	---	2700	1,774	1.17	100% saturation
J28-2	90°	72	3.98	1.30	3.98	---	2900	1,774	1.17	100% saturation
J28-8	90°	72	3.94	1.33	3.94	---	2900	1,774	1.17	100% saturation
Avg.			4.03	1.41	3.83	---	2800		1.17	
Std.Dev			0.18	0.10	0.59	---	100		0.02	
J26-7	90°	260	1.87	1.20	1.06	---	1600	1,774	1.16	100% saturation
J29-7	90°	260	1.99	1.11	1.37	---	1900	1,774	1.17	100% saturation
J30-1	90°	260	1.21	1.13	0.69	---	1100	1,774	1.15	100% saturation
J30-5	90°	260	1.26	0.88	1.07	---	1500	1,774	1.17	100% saturation
J30-8	90°	260	1.09	0.83	1.09	---	1300	1,774	1.18	100% saturation
Avg.			1.49	1.03	1.05	---	1480		1.17	
Std.Dev			0.42	0.16	0.24	---	300		0.01	

Test: Tension After Environmental Aging @ 160°F & 100% R.H. **Material:** G-160/6535-1

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (μin/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
K14-6	90°	72	3.32	1.64	3.32	---	2050	216	0.69	50% saturation
K14-10	90°	72	3.85	1.77	3.85	---	2200	216	0.65	50% saturation
K15-8	90°	72	4.11	1.79	4.11	---	2270	216	0.67	50% saturation
K16-9	90°	72	4.14	1.72	4.14	---	2410	216	0.68	50% saturation
K18-10	90°	72	3.78	1.52	3.78	---	2480	216	0.66	50% saturation
Avg.			3.84	1.69	3.84	---	2280		0.67	
Std.Dev			0.33	0.11	0.33	---	170		0.02	
K16-8	90°	260	1.93	1.78	1.33	---	1150	216	0.67	50% saturation
K17-9	90°	260	2.55	1.61	1.59	---	1700	216	0.70	50% saturation
K15-9	90°	260	2.58	1.52	1.78	---	1750	216	0.68	50% saturation
K45-9	90°	260	2.62	1.26	1.87	---	2150	216	0.66	50% saturation
K18-8	90°	260	2.39	1.09	1.98	---	2230	216	0.69	50% saturation
Avg.			2.41	1.45	1.71	---	1800		0.68	
Std.Dev			0.29	0.28	0.26	---	430		0.02	
K14-4	90°	72	2.56	1.66	2.56	---	1450	3388	1.29	100% saturation
K15-5	90°	72	1.95	1.78	1.95	---	1100	3388	1.29	100% saturation
K16-6	90°	72	2.42	1.80	2.42	---	1400	3388	1.27	100% saturation
K17-6	90°	72	2.25	1.61	2.25	---	1420	3388	1.30	100% saturation
K18-9	90°	72	1.72	1.41	1.72	---	1230	3388	1.29	100% saturation
Avg.			2.18	1.65	2.18	---	1320		1.29	
Std.Dev			0.34	0.16	0.34	---	150		0.01	
K14-3	90°	260	1.67	1.27	0.59	---	1730	3388	1.29	100% saturation
K15-7	90°	260	1.61	1.34	0.58	---	1380	3388	1.28	100% saturation
K17-5	90°	260	1.53	1.38	0.46	---	1450	3388	1.31	100% saturation
K18-5	90°	260	1.52	1.06	0.53	---	1630	3388	1.28	100% saturation
K45-5	90°	260	1.61	1.17	0.75	---	1670	3388	1.27	100% saturation
Avg.			1.59	1.24	0.58	---	1570		1.29	
Std.Dev			0.06	0.13	0.11	---	150		0.01	

APPENDIX P

HUMIDITY AGED COMPRESSION DATA

All of the compression data generated during this program on specimens which had been humidity aged at 160°F (71°C) and 100% R.H. are presented in this section.

Summaries of these data are tabulated and plotted in the form of stress-strain curves in Sections 4.1 through 4.6.

Test: Compression After Environmental Aging @ 160°F & 100% R.H. Material: T300/AFR800

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (μin/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
F35-7	90°	72	31.56	1.80	9.49	---	22,000	116	0.65	(1)
F35-19	90°	72	31.66	1.83	17.59	---	51,800	116	0.70	(1)
F35-29	90°	72	34.40	1.46	30.40	---	30,500	116	0.64	(1)
F36-1	90°	72	36.62	1.89	9.69	---	53,000	116	0.64	(1)
F36-16	90°	72	31.82	1.52	4.27	---	48,000	116	0.66	(1)
Avg.			32.92	1.70	14.29	---	41,100		0.66	
Std.Dev			2.47	0.20	10.19	---	14,000		0.02	
F35-4	90°	260	24.81	1.34	8.49	---	41,800	164	0.86	(1)
F35-13	90°	260	24.39	1.53	10.51	---	54,000	164	0.86	(1)
F35-16	90°	260	26.13	1.50	10.58	---	34,500	164	0.79	(1)
F36-11	90°	260	26.46	3.38	5.64	---	18,000	164	0.78	(1)
F36-17	90°	260	28.09	1.46	13.2	---	32,800	164	0.80	(1)
Avg.			25.98	1.84	9.69	---	36,200	164	0.81	
Std.Dev			1.47	0.86	2.82	---	13,200		0.03	
F35-10	90°	72	---	---	---	---	---	1904	1.27	(2)
F35-22	90°	72	33.82	2.31	8.92	---	37,000	1904	1.26	(2)
F36-12	90°	72	33.06	1.75	33.06	---	21,000	1904	1.34	(2)
F36-24	90°	72	29.69	1.35	9.41	---	54,300	1904	1.12	(2)
Avg.			32.19	1.80	17.13	---	37,400		1.25	
Std.Dev			2.19	0.48	13.80	---	16,700		0.10	
F35-12	90°	260	23.12	1.38	14.81	---	34,300	1904	1.34	(2)
F36-4	90°	260	25.93	2.23	10.87	---	13,000	1904	1.33	(2)
F36-10	90°	260	22.71	1.45	9.79	---	44,500	1904	1.35	(2)
F36-20	90°	260	24.69	1.46	10.61	---	43,600	1904	1.32	(2)
Avg.			24.11	1.63	11.52	---	33,900		1.34	
Std.Dev			1.48	0.40	2.24	---	14,600		0.02	

(1) 50% saturation (2) 100% saturation

Test: Compression After Environmental Aging @ 160°F & 100% R.H. Material: SIC/5506

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (μin/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
G42-2	90°	72	30.41	4.59	4.34	---	32,100	162.5	0.83	(1)
G42-12	90°	72	31.44	3.14	7.85	---	33,000	162.5	0.64	(1)
G42-22	90°	72	29.88	5.25	18.29	---	7,100	162.5	0.79	(1), (3)
G42-38	90°	72	28.99	4.17	4.07	---	31,400	162.5	0.78	(1)
G42-54	90°	72	26.90	3.82	3.61	---	5,700	162.5	0.76	(1), (3)
Avg.			29.52	4.19	7.63	---	32,200		0.76	excludes G42-22 &
Std.Dev			1.71	0.79	6.19	---	800		0.07	G42-54
G42-3	90°	260	19.77	3.14	5.50	---	5,300	162.5	0.78	(1), (3)
G42-5	90°	260	17.52	3.37	7.44	---	5,000	162.5	0.80	(1), (3)
G42-8	90°	260	18.45	2.04	6.53	---	8,000	162.5	0.75	(1), (3)
G42-13	90°	260	19.29	2.63	5.19	---	7,400	162.5	0.79	(1), (3)
G42-28	90°	260	19.12	3.87	3.75	---	27,400	162.5	0.82	(1), (3)
Avg.			18.83	3.01	5.68	---	10,620		0.79	
Std.Dev			0.87	0.70	1.40	---	9,470		0.03	
G42-4	90°	72	25.71	2.33	11.22	---	17,900	1,752	---	(2)
G42-16	90°	72	24.69	2.72	8.15	---	18,200	1,752	1.41	(2)
G42-20	90°	72	24.05	2.51	11.42	---	19,000	1,752	1.22	(2)
G42-49	90°	72	23.77	3.90	5.33	---	32,100	1,752	1.30	(2)
G42-50	90°	72	24.09	2.79	15.39	---	15,200	1,752	1.31	(2)
Avg.			24.46	2.85	10.30	---	20,480		1.31	
Std.Dev			0.77	0.61	3.79	---	6,650		0.08	
G42-9	90°	260	18.96	3.18	9.73	---	14,700	1,752	1.31	(2)
G42-23	90°	260	16.46	2.90	11.59	---	5,970	1,752	1.32	(2)
G42-24	90°	260	17.59	2.81	8.78	---	21,600	1,752	1.31	(2)
G42-30	90°	260	19.98	4.70	15.45	---	3,470	1,752	1.29	(2), (3)
G42-43	90°	260	15.58	3.03	9.41	---	10,000	1,752	1.32	(2)
Avg.			17.71	3.32	10.99	---	11,150		1.31	
Std.Dev			1.79	0.78	2.70	---	7,230		0.01	

(1) 50% saturation (2) 100% saturation (3) Evidence of buckling

Test: Compression After Environmental Aging @ 160°F & 100% R.H. Material: HYE 2034D

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (μin/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
H29-12	90°	72	12.00	3.02	3.35	---	13200	144.5	0.75	(1)
H29-33	90°	72	14.50	1.91	1.89	---	19500	144.5	0.78	(1)
H30-4	90°	72	17.59	1.26	3.51	---	30700	144.5	0.73	(1)
H30-18	90°	72	12.39	1.47	2.58	---	18500	144.5	0.70	(1)
Avg.			14.12	1.92	2.83	---	20480		0.74	
Std.Dev			2.56	0.79	0.75	---	7360		0.03	
H29-14	90°	260	11.26	1.07	2.47	---	17500	144.5	0.76	(1)
H29-26	90°	260	12.80	2.00	2.38	---	22000	144.5	0.79	(1)
H29-18	90°	260	15.62	1.39	2.23	---	17700	144.5	0.79	(1)
H30-10	90°	260	13.56	1.08	2.87	---	23500	144.5	0.75	(1)
H30-15	90°	260	13.70	1.38	---	---	11750	144.5	0.73	(1)
Avg.			13.39	1.39	2.49	---	18490		0.76	
Std.Dev.			1.58	0.38	0.27	---	4600		0.03	
H29-3	90°	72	14.73	1.18	6.25	---	14600	1706.25	1.29	(2)
H29-8	90°	72	14.57	0.89	6.79	---	19200	1706.25	1.32	(2)
H29-27	90°	72	13.75	1.17	6.42	---	12300	2182.75	1.32	(2)
H29-30	90°	72	13.55	0.96	3.53	---	13800	2182.75	1.37	(2)
H30-8	90°	72	19.34	1.07	4.92	---	16000	2182.75	1.35	(2)
Avg.			15.19	1.05	5.58	---	15180		1.33	
Std.Dev.			2.38	0.13	1.35	---	2620		0.03	
H29-1	90°	260	13.33	1.22	2.10	---	19500	2182.75	1.25	(2)
H29-4	90°	260	---	1.04	2.09	---	---	2182.75	1.57	(2),(3)
H30-5	90°	260	14.15	0.96	3.33	---	25900	2182.75	1.36	(2)
H30-11	90°	260	17.05	1.27	3.76	---	13400	2182.75	1.32	(2)
H30-13	90°	260	19.63	0.86	---	---	18300	2182.75	1.39	(2)
Avg.			16.04	1.07	2.82	---	19280		1.38	
Std.Dev			2.88	0.17	0.86	---	5140		0.12	

(1) 50% saturation (2) 100% saturation (3) Damaged before test

Test: Compression After Environmental Aging @ 160°F & 100% R.H. Material: T300/V378A

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (μin/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
I42-21	90°	72°	26.99	1.96	1.53	---	25,500	17.5	0.73	(1)
I42-29	90°	72	25.73	1.79	1.82	---	36,300	17.5	0.64	(1)
I42-43	90°	72	25.35	2.56	1.98	---	43,800	17.5	0.64	(1)
I42-50	90°	72	21.77	1.94	1.77	---	30,600	17.5	0.70	(1)
I42-54	90°	72	21.17	1.54	1.61	---	22,800	17.5	0.72	(1)
Avg.			24.20	1.96	1.74	---	31,800		0.69	
Std.Dev			2.57	0.36	0.18	---	8,460		0.04	
I42-5	90°	350	20.12	1.95	1.29	---	11,700	17.5	0.70	(1),(3)
I42-34	90°	350	20.41	2.13	2.43	---	29,500	17.5	0.76	(1)
I42-45	90°	350	17.36	1.42	1.10	---	29,700	17.5	0.72	(1)
I42-51	90°	350	16.99	1.21	5.22	---	11,800	17.5	0.71	(1),(3)
I42-58	90°	350	16.77	1.29	1.76	---	13,800	17.5	0.67	(1),(3)
Avg.			18.33	1.60	2.36	---	29,600*		0.71	*excludes I42-5,
Std.Dev			1.78	0.41	1.68	---	---		0.03	I42-51, I42-58
I42-7	90°	72	24.88	2.76	2.72	---	11,900	2,471	1.33	(2),(3)
I42-11	90°	72	24.52	2.47	5.05	---	30,900	2,471	1.33	(2)
I42-23	90°	72	25.97	1.71	5.09	---	32,500	2,471	1.36	(2)
I42-27	90°	72	24.92	2.86	4.52	---	11,500	2,471	1.33	(2),(3)
I42-31	90°	72	26.34	2.45	4.28	---	12,900	2,471	1.33	(2),(3)
Avg.			25.33	2.45	4.33	---	31,700*		1.34	*excludes I42-7,
Std.Dev			0.79	0.45	0.97	---	---		0.01	I42-27, I42-31
I42-35	90°	350	16.93	3.55	2.60	---	26,200	2,471	1.38	(2)
I42-39	90°	350	17.07	1.13	4.22	---	15,500	2,471	1.34	(2)
I42-46	90°	350	21.97	3.68	2.21	---	33,400	2,471	1.37	(2)
I42-53	90°	350	20.36	2.60	3.43	---	11,500	2,471	1.36	(2),(3)
I42-55	90°	350	20.53	1.89	3.54	---	11,800	2,471	1.35	(2),(3)
Avg.			19.37	2.57	3.20	---	25,030*		1.36	*excludes I42-53,
Std.Dev			2.25	1.09	0.80	---	9,010*		0.02	I42-55

(1) 50% saturation (2) 100% saturation (3) Evidence of buckling

Test: Compression After Environmental Aging @ 160°F & 100% R.H. Material: HYE 1076J

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop.Lim. (ksi)	Pois. Ratio	Ult. Strain (μin/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
J31-13	90°	72	28.30	2.06	5.36	---	28200	161	0.74	(1)
J31-37	90°	72	24.25	2.42	4.81	---	24300	161	0.80	(1)
J31-41	90°	72	23.98	2.11	1.81	---	21700	161	0.75	(1)
J31-54	90°	72	25.45	2.27	3.02	---	11600	161	0.68	(1)
Avg.			25.50	2.22	3.75	---	21450		0.74	
Std.Dev			1.98	.16	1.63	---	7090		0.05	
J31-3	90°	260	21.28	2.00	3.69	---	15900	161	0.69	(1)
J31-11	90°	260	19.19	2.04	2.81	---	11300	161	0.78	(1)
J31-30	90°	260	24.33	1.43	6.16	---	34700	161	0.68	(1)
J31-47	90°	260	20.17	2.44	2.91	---	12800	161	0.76	(1)
J31-51	90°	260	19.24	1.62	4.39	---	9500	161	0.78	(1),(3)
Avg.			20.84	1.91	3.99	---	18680*		0.74	*excludes J31-51
Std.Dev			2.13	0.39	1.37	---	10850*		0.05	
J31-1	90°	72	21.8	1.86	13.7	---	9400	1,242	1.04	(2),(3)
J31-14	90°	72	24.2	1.77	12.5	---	25400	1,242	1.08	(2)
J31-16	90°	72	26.4	1.40	6.9	---	26600	1,242	1.09	(2)
J31-24	90°	72	25.9	1.71	9.9	---	14300	1,242	1.07	(2),(3)
J31-40	90°	72	29.3	1.43	8.9	---	43100	1,242	0.97	(2)
Avg.			25.5	1.63	10.4	---	31700*		1.05	*excludes J31-1,
Std.Dev			2.8	0.21	2.7	---	9890*		0.05	J31-24
J31-8	90°	260	17.9	2.38	10.0	---	11600	1,242	1.09	(2)
J31-32	90°	260	18.9	1.76	5.9	---	32000	1,242	1.08	(2)
J31-44	90°	260	16.8	1.69	5.8	---	20800	1,242	1.07	(2)
J31-52	90°	260	20.3	1.15	4.6	---	17900	1,242	1.12	(2)
J31-56	90°	260	23.4	1.22	7.1	---	28800	1,242	1.08	(2)
Avg.			19.5	1.64	6.7	---	22220		1.09	
Std.Dev			2.6	0.50	2.1	---	8250		0.02	

(1) 50% saturation (2) 100% saturation (3) Evidence of buckling

Test: Compression **After Environmental Aging @ 160°F & 100% R.H.** **Material:** G-160/6535-1

Spec. No.	Fiber Orien.	Test Temp. (°F)	Ult. Strgth. (ksi)	Init. Mod. (10^6 psi)	Stress at Prop. Lim. (ksi)	Pois. Ratio	Ult. Strain (μin/in)	Exposure Time (hrs)	Weight Gain (%)	Remarks
K19-8	90°	72	30.65	1.75	7.82	---	16,900	166.5	0.63	Evidence of buckling
K19-32	90°	72	25.85	1.78	14.63	---	26,000	166.5	0.61	50% saturation
K44-6	90°	72	29.98	---	3.35	---	---	166.5	0.62	50% saturation
K44-10	90°	72	28.51	1.79	14.06	---	29,000	166.5	0.61	50% saturation
K44-29	90°	72	28.89	1.90	5.50	---	20,000	166.5	0.65	50% saturation
Avg.			28.78	1.81	9.07	---	22,980		0.62	
Std.Dev			1.84	0.06	5.07	---	5,510		0.02	
K19-38	90°	260	18.37	1.59	7.17	---	7,900	166.5	0.61	Evidence of buckling
K44-5	90°	260	21.30	1.43	8.48	---	36,000	166.5	0.62	50% saturation
K44-7	90°	260	20.76	1.45	4.39	---	35,000	166.5	0.64	50% saturation
K44-16	90°	260	22.33	1.25	6.80	---	36,000	166.5	0.65	50% saturation
K44-26	90°	260	20.12	1.31	6.10	---	31,000	166.5	0.63	50% saturation
Avg.			20.58	1.41	6.59	---	29,180		0.63	
Std.Dev			1.48	0.13	1.50	---	12,070		0.02	
K19-31	90°	72	28.80	1.70	15.60	---	19,450	1532	1.22	100% saturation
K19-39	90°	72	23.28	1.43	13.20	---	30,500	1532	1.21	100% saturation
K44-14	90°	72	29.04	1.71	11.92	---	29,500	1532	1.23	100% saturation
K44-15	90°	72	28.27	1.64	7.12	---	27,100	1532	1.22	100% saturation
K44-20	90°	72	---	---	---	---	---	---	---	failed in handling
Avg.			27.35	1.62	11.96	---	26,640		1.22	
Std.Dev			2.73	0.13	3.57	---	5,000		0.01	
K19-7	90°	260	18.74	1.63	4.20	---	12,700	3621	1.27	Evidence of buckling
K19-29	90°	260	16.90	1.63	2.97	---	28,000	3621	1.24	100% saturation
K19-33	90°	260	16.17	1.46	3.68	---	26,000	3621	1.28	100% saturation
K19-44	90°	260	16.49	1.66	2.48	---	31,000	3621	1.28	100% saturation
K44-9	90°	260	18.43	1.64	3.26	---	36,000	3621	1.28	100% saturation
Avg.			17.34	1.61	3.32	---	26,740		1.27	
Std.Dev			1.16	0.08	0.66	---	8,710		0.02	

APPENDIX Q

HUMIDITY AGED INTERLAMINAR SHEAR DATA

All of the interlaminar shear data generated during this program on specimens which had been humidity aged at 160°F (71°C) and 100% R.H. are presented in this section. These data are summarized in Sections 4.1 through 4.6.

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.					
Materials: T300/AFR800			L/D Ratio: 4/1		
Specimen Number	Test Temp. (°F)	Ultimate Strength (ksi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
F21-4	72	15.88	27	0.63	50% saturation
F21-5	72	16.66	27	0.62	50% saturation
F21-13	72	16.62	27	0.62	50% saturation
F21-19	72	15.35	27	0.80	50% saturation
F21-21	72	14.73	27	0.54	50% saturation
F21-25	72	15.45	27	0.83	50% saturation
F21-32	72	14.54	27	0.42	50% saturation
F21-34	72	16.27	27	0.65	50% saturation
F21-37	72	16.31	27	0.92	50% saturation
F21-38	72	14.90	27	0.63	50% saturation
Avg.		15.64		0.67	
Std. Dev.		0.79		0.15	
F21-47	260	10.60	27	0.52	50% saturation
F21-50	260	11.19	27	0.77	50% saturation
F21-62	260	10.08	27	1.06	50% saturation
F21-63	260	10.25	27	0.82	50% saturation
F21-70	260	10.68	27	0.72	50% saturation
Avg.		10.56		0.78	
Std. Dev.		0.43		0.19	

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.

Materials: T300/AFR300 L/D Ratio: 4/1

Specimen Number	Test Temp. (°F)	Ultimate Strength (ksi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
F21-1	72	14.12	1286	1.01	saturation
F21-8	72	14.75	1286	1.17	saturation
F21-17	72	13.65	1286	1.19	saturation
F21-22	72	14.57	1286	1.33	saturation
F21-29	72	13.34	1286	1.37	saturation
F21-31	72	13.38	1286	1.55	saturation
F21-40	72	14.14	1286	1.02	saturation
F21-42	72	13.87	1286	1.33	saturation
F21-52	72	12.85	1286	1.35	saturation
F21-59	72	12.92	1286	1.26	saturation
Avg.		13.78		1.26	
Std. Dev.		0.64		0.17	
F21-2	260	7.41	1286	1.39	saturation
F21-28	260	7.52	1286	1.31	saturation
F21-30	260	7.38	1286	1.36	saturation
F21-39	260	7.43	1286	1.96	saturation
F21-60	260	7.63	1286	1.19	saturation
Avg.		7.47		1.24	
Std. Dev.		0.10		0.18	

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.

Materials: SiC/5506 L/D Ratio: 4/1

Specimen Number	Test Temp. (°F)	Ultimate Strength (ksi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
G38-7	72	11.09	384	0.65	50% saturated
G38-15	72	11.07	384	0.45	50% saturated
G38-19	72	11.53	384	0.72	50% saturated
G38-27	72	11.87	384	0.49	50% saturated
G38-37	72	12.06	384	0.64	50% saturated
G38-45	72	11.59	384	0.69	50% saturated
G38-49	72	11.77	384	0.71	50% saturated
G38-52	72	11.49	384	0.66	50% saturated
G38-55	72	11.76	384	0.65	50% saturated
G38-64	72	11.85	384	0.66	50% saturated
Avg.		11.61		0.63	
Std. Dev.		0.33		0.09	
G38-10	260	6.30	384	0.51	50% saturated
G38-21	260	6.98	384	0.90	50% saturated
G38-43	260	7.00	384	0.63	50% saturated
G38-59	260	6.67	384	0.67	50% saturated
G38-66	260	6.98	384	0.63	50% saturated
Avg.		6.79		0.67	
Std. Dev.		0.30		0.14	

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.					
Materials: SiC/5506			L/D Ratio: 4/1		
Specimen Number	Test Temp. (°F)	Ultimate Strength (ksi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
G38-3	72	10.85	240	1.06	saturation
G38-14	72	10.74	240	0.92	saturation
G38-22	72	12.46	240	1.85	saturation
G38-26	72	12.56	240	1.49	saturation
G38-32	72	12.57	240	0.88	saturation
G38-34	72	12.57	240	0.90	saturation
G38-35	72	12.57	240	1.06	saturation
G38-38	72	12.59	240	0.87	saturation
G38-46	72	12.08	240	0.93	saturation
G38-50	72	12.16	240	0.96	saturation
G38-65	72	11.57	240	0.84	saturation
Avg.		12.06		1.07	
Std. Dev.		0.70		0.31	
G38-18	260	7.25	335	1.02	saturation
G38-29	260	7 14	335	0.96	saturation
G38-42	260	7.04	335	1.47	saturation
G38-53	260	7.01	335	1.07	saturation
G38-62	260	7.31	335	0.93	saturation
Avg.		7.15		1.09	
Std. Dev.		0.13		0.21	

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.

Materials: HYE 2034D   L/D Ratio: 4/1

Specimen Number	Test Temp. (°F)	Ultimate Strength (ksi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
H31-9	72	7.36	167	0.77	50% saturated
H31-13	72	7.64	167	0.65	50% saturated
H31-23	72	7.24	167	0.72	50% saturated
H31-27	72	6.89	167	0.84	50% saturated
H31-32	72	6.44	167	0.67	50% saturated
H31-52	72	6.59	167	0.73	50% saturated
H31-60	72	7.13	167	0.70	50% saturated
H31-61	72	6.67	167	0.79	50% saturated
H31-43	72	7.32	167	0.68	50% saturated
H31-33	72	6.91	167	0.60	50% saturated
Avg.		7.02		0.72	
Std. Dev.		0.38		0.07	
H31-4	260	5.87	167	0.72	50% saturated
H31-11	260	5.33	167	0.55	50% saturated
H31-15	260	5.50	167	0.60	50% saturated
H31-62	260	5.46	167	0.92	50% saturated
H31-45	260	5.61	167	0.76	50% saturated
Avg.		5.56		0.71	
Std. Dev.		.20		0.15	

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.					
Materials: HYE 2034D			L/D Ratio: 4/1		
Specimen Number	Test Temp. (°F)	Ultimate Strength (ksi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
H31-6	72	7.40	862	1.45	saturated
H31-14	72	7.29	862	1.15	saturated
H31-18	72	7.35	862	1.26	saturated
H31-25	72	7.68	862	1.66	saturated
H31-26	72	6.99	862	1.51	saturated
H31-29	72	6.39	862	1.63	saturated
H31-31	72	7.35	862	1.38	saturated
H31-38	72	7.16	862	1.33	saturated
H31-39	72	7.08	862	1.36	saturated
H31-50	72	7.43	862	1.19	saturated
Avg.		7.21		1.39	
Std. Dev.		0.35		0.17	
H31-37	260	4.32	862	1.26	saturated
H31-58	260	4.14	862	1.33	saturated
H31-65	260	4.16	862	1.30	saturated
H31-63	260	3.69	862	1.67	saturated
H31-67	260	4.14	862	1.31	saturated
Avg.		4.09		1.37	
Std. Dev.		.24		0.17	

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.

Materials: T300/V378A L/D Ratio: 4/1

Specimen Number	Test Temp. (°F)	Ultimate Strength (ksi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
I 15-5	72°	14.40	<48[1]	0.79	50% saturation
I 15-11	72°	13.45	<48[1]	0.86	50% saturation
I 15-15	72°	13.67	<48[1]	0.85	50% saturation
I 15-19	72°	14.16	<48[1]	0.81	50% saturation
I 15-23	72°	13.86	<48[1]	0.70	50% saturation
I 15-30	72°	14.03	<48[1]	0.74	50% saturation
I 15-44	72°	14.33	<48[1]	0.46	50% saturation
I 15-46	72°	13.96	<48[1]	0.76	50% saturation
I 15-50	72°	14.19	<48[1]	0.65	50% saturation
I 15-52	72°	13.88	<48[1]	0.81	50% saturation
Avg.		13.99		0.74	
Std. Dev.		0.29		0.12	
I 15-54	350°	8.71	<48[1]	0.65	50% saturation
I 15-57	350°	8.69	<48[1]	0.72	50% saturation
I 15-60	350°	7.84	<48[1]	0.74	50% saturation
I 15-72	350°	9.70	<48[1]	0.77	50% saturation
I 15-73	350°	9.59	<48[1]	0.74	50% saturation
Avg.		8.91		0.72	
Std. Dev.		0.76		0.05	

[1]Specimens gained weight so rapidly that they were already saturated at first weighing (48 hrs.). They were dried in a dessicator at 72° f and 0% R.H. for 116 hr. to reach weight gain indicated.

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.					
Materials: T300/V378A			L/D Ratio: 4/1		
Specimen Number	Test Temp. (°F)	Ultimate Strength (ksi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
I 15-3	72°	14.49	138	1.17	saturated
I 15-7	72°	13.60	138	1.22	saturated
I 15-22	72°	14.47	138	1.29	saturated
I 15-31	72°	14.53	138	0.94	saturated
I 15-33	72°	14.24	138	1.32	saturated
I 15-35	72°	14.47	138	1.27	saturated
I 15-36	72°	14.61	138	1.23	saturated
I 15-40	72°	13.99	138	1.17	saturated
I 15-42	72°	15.04	138	1.27	saturated
I 15-48	72°	14.18	138	1.12	saturated
Avg.		14.36		1.20	
Std. Dev.		0.39		0.11	
I 15-51	350°	8.14	138	1.15	saturated
I 15-53	350°	7.32	138	1.28	saturated
I 15-55	350°	7.55	138	1.11	saturated
I 15-58	350°	7.04	138	1.22	saturated
I 15-77	350°	7.39	138	1.44	saturated
Avg.		7.49		1.24	
Std. Dev.		0.41		0.13	

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.					
Materials: HyE 1076J			L/D Ratio: 4/1		
Specimen Number	Test Temp. (°F)	Ultimate Strength (ksi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
J26-20	72	9.62	188	0.38	50% saturated
J26-25	72	11.27	188	0.54	50% saturated
J26-28	72	10.58	188	0.73	50% saturated
J26-58	72	12.87	188	0.30	50% saturated
J26-68	72	15.17	188	0.77	50% saturated
J26-71	72	13.41	188	0.51	50% saturated
J26-79	72	11.17	188	0.53	50% saturated
J26-36	72	12.61	188	0.51	50% saturated
J26-50	72	10.14	188	0.42	50% saturated
J26-62	72	11.91	188	0.82	50% saturated
Avg.		11.88		0.55	
Std. Dev.		1.68		0.17	
J26-31	260	6.45	188	0.65	50% saturated
J26-43	260	7.06	188	0.98	50% saturated
J26-45	260	9.43	188	0.34	50% saturated
J26-55	260	9.92	188	0.37	50% saturated
J26-75	260	9.34	188	0.84	50% saturated
Avg.		8.44		0.64	
Std. Dev.		1.57		0.28	

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.					
Materials: HyE 1076J			L/D Ratio: 4/1		
Specimen Number	Test Temp. (°F)	Ultimate Strength (ksi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
J26-11	72	13.41	1,675	0.98	saturated
J26-24	72	11.42	1,675	1.02	saturated
J26-32	72	9.42	1,675	1.16	saturated
J26-42	72	10.39	1,675	0.91	saturated
J26-47	72	12.59	1,675	1.03	saturated
J26-60	72	11.67	1,675	0.99	saturated
J26-65	72	11.02	1,675	1.17	saturated
J26-72	72	14.04	1,675	1.14	saturated
J26-82	72	14.11	1,675	1.28	saturated
J26-87	72	11.70	1,675	1.45	saturated
Avg.		11.98		1.11	
Std. Dev.		1.55		0.16	
J26-15	260	6.44	1,675	1.19	saturated
J26-39	260	6.64	1,675	1.15	saturated
J26-54	260	6.62	1,675	1.24	saturated
J26-63	260	6.72	1,675	1.17	saturated
J26-76	260	7.78	1,675	1.28	saturated
Avg.		6.84		1.21	
Std. Dev.		0.54		0.05	

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.					
Materials: G-160/6535-1			L/D Ratio: 4/1		
Specimen Number	Test Temp. (°F)	Ultimate Strength (psi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
K18-7	72	13.56	91	0.50	50% saturated
K18-9	72	14.05	91	0.60	50% saturated
K18-11	72	14.65	91	0.68	50% saturated
K18-19	72	14.46	91	0.60	50% saturated
K18-33	72	13.79	91	0.47	50% saturated
K18-40	72	13.97	91	0.42	50% saturated
K18-50	72	13.70	91	0.48	50% saturated
K18-54	72	15.08	91	0.54	50% saturated
K18-59	72	14.82	91	0.64	50% saturated
K18-61	72	14.56	91	0.60	50% saturated
Avg.		14.26		0.55	
Std. Dev.		0.52		0.08	
K18-21	260	8.40	91	0.63	50% saturated
K18-36	260	8.97	91	0.55	50% saturated
K18-42	260	9.86	91	0.56	50% saturated
K18-56	260	9.44	91	0.44	50% saturated
K18-60	260	9.76	91	0.59	50% saturated
Avg.		9.28		0.56	
Std. Dev.		0.60		0.07	

Test: Interlaminar (Short-Beam) Shear After Environmental Aging at 160°F and 100% R.H.					
Materials: G-160/6535-1			L/D Ratio: 4/1		
Specimen Number	Test Temp. (°F)	Ultimate Strength (psi)	Exposure Time (Hrs)	Weight Gain (%)	Remarks
K18-3	72	12.00	1530	1.20	Saturated
K18-5	72	10.99	1530	1.12	Saturated
K18-13	72	11.83	1530	1.17	Saturated
K18-17	72	12.56	1530	0.99	Saturated
K18-24	72	12.77	1530	1.38	Saturated
K18-27	72	12.62	1530	0.84	Saturated
K18-30	72	11.46	1530	1.15	Saturated
K18-43	72	12.81	1530	1.20	Saturated
K18-53	72	12.96	1530	1.24	Saturated
K18-58	72	13.28	1530	1.25	Saturated
Avg.		12.33		1.15	
Std. Dev.		0.73		0.15	
K18-4	260	6.28	1530	1.05	Saturated
K18-8	260	6.50	1530	1.23	Saturated
K18-15	260	6.57	1530	1.03	Saturated
K18-29	260	6.57	1530	1.26	Saturated
K18-39	260	6.62	1530	1.65	Saturated
Avg.		6.51		1.13	
Std. Dev.		0.14		0.11	